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COMMUNICATIONS

OBSERVATIONS ON THE CHOROIDAL CIRCULATION*

BY

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THE discovery of aqueous veins and subsequent studies of their significance in health and disease have been responsible in no small measure for a new impetus to research work in the aetiology of glaucoma, which in turn has necessitated a re-examination of our fundamental knowledge of the anatomy and physiology of the ocular circulation and the drainage of the aqueous humour, with particular reference to the ocular tension. Amid the abundant recent literature on these subjects are a few papers directing attention towards the minute anatomy of the choroidal circulation, and the findings reported would be of very great importance if the evidence could be regarded as conclusive. It is the purpose of this paper to discuss these reports in the light of our own experience, and to introduce a technique which is likely to prove of value in future work in this field.

The anatomy of the small vessels in such a structure as the choroid cannot be studied adequately by the methods at present in use. It is impossible to reconstruct complicated minute branches and anastomoses from serial sections; dye injection preparations, while of much greater value, are not suitable for dissection and are, therefore, prone to misinterpretation. The earlier investigators, using an injection mass of vermillion and size, were much nearer to the ideal technique. In a previous publication, the value of Neoprene latex in the study of Schlemm's canal and aqueous veins has already been demonstrated (Ashton, 1951, 1952) and we have now applied this technique to a study of the choroidal circulation. We are using Neoprene casts, together with flat sections and bulk preparations, to investigate the possible existence of arterio-venous anastomoses, with or without a glomus-like apparatus, in the choroidal circulation both in normal and pathological conditions.

Methods

Neoprene Casts of the Choroid.—At *post mortem*, after the brain has been taken for examination, the orbital contents are separated from the bony margin, from all sides up to the apex of the orbit, and the orbital roof is removed from the interior of the skull. A sagittal incision is made through the bone of the sella turcica and, by chiselling through the sphenoid bone under the cavernous sinus, the whole of the orbital contents, together with the optic nerve and the cavernous portion of the internal carotid artery, may be removed *in toto*.

The specimen is taken direct to the laboratory, where the internal carotid artery is slit down to reveal the opening of the ophthalmic artery. A glass cannula is inserted into this opening, and the vessels are then irrigated with tap water, any large leaking vessels

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FIG. 1.—White Neoprene cast of choroid viewed from without, showing layer of large and medium vessels and chorio-capillaris beyond. Equatorial region. × 66.

being secured with artery forceps and ligatured. After irrigation has been carried out for one hour, the specimen is placed in the refrigerator overnight to promote haemolysis in any remaining clots. The next morning the vessels are again irrigated for about 15 minutes.

Neoprene latex 572 diluted 1 in 3, either white or coloured red,* is injected from a Wolff's bottle, under 10 lb. pressure from an electric pump. In order to force the Neoprene into the finest vessels it is important to make the initial injection under maximum pressure. This can be achieved by clamping the tubing on to the cannula side of the Wolff's bottle, switching on the pump, and then releasing the clamp after a few seconds.

When the injection is complete the specimen is fixed in 10 per cent. formol saline; the eye is then cut equatorially through the ora serrata, the vitreous and retina are removed, and the choroid is carefully dissected out by severing its vascular and nervous connections to the sclera. The injected choroid is then floated out of the sclera and bleached in 2 per cent. potassium oxalate for 15–30 min., followed by washing and 1 per cent. oxalic acid.

If the injection has been successful, the whole choroidal circulation may be seen perfectly, even to its finest detail (Figs 1 and 2); it may be studied whole in a glass sphere the same size as the sclera, or cut radially and mounted flat—a more

* As supplied from B.B. Chemical Co., Ltd., Ulverscroft Road, Leicester, England.

FIG. 2.—Another view of cast shown in Fig. 1. The vessels may be studied by micro-dissection. The complexity of the vascular network, as shown in the cast, demonstrates the futility of attempting to determine their connections by serial sections. Equatorial region. × 45.

satisfactory preparation for photographic purposes. If the vessels have been injected with red Neoprene the arteries will appear an intense red and the veins a delicate pink; a differentiation most useful for purposes of identification (Figs 3 and 4, overleaf). It is not clear why this occurs; presumably the pressure propels the Neoprene further than the vermillion granules so that the more proximal vessels tend to contain a higher proportion of pigment. Even with white Neoprene some differentiation is possible, because the thicker arterial walls impart a dense white appearance to the cast, whereas the thin-walled veins appear greyish-white.

It is occasionally of value to digest the tissue in pepsin and trypsin, as described in the technique for preparing casts of Schlemm's canal; this allows complete dissection of the choroidal vessels, and the observer may decide with certainty at which points the vessels anastomose. On the other hand, if the bleached tissue is allowed to remain, the vessels are retained in their correct anatomical relationship.

Histological Techniques

Flat Bulk Preparations :

Bleached choroid stained with haematoxylin and eosin, cleared and mounted in polystyrene.
Bleached choroid stained with haemalum, cleared and mounted in polystyrene.
Bleached choroid stained by Holmes's silver method, cleared and mounted in polystyrene.
Bleached choroid stained with haemalum and mounted in glycerine.

FIG. 3.—Red Neoprene cast of choroid viewed from without. The arteries appeared in red and the veins in pink. Note the characteristic loop at the origin of a vein. The direct capillary connections between artery and vein are well shown. Anterior region. × 28.

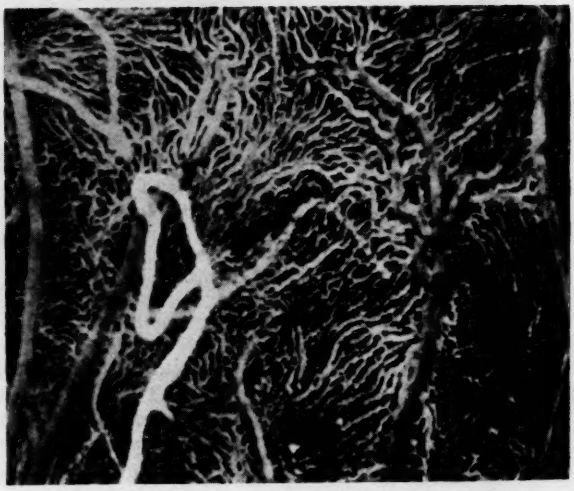

FIG. 4.—Red Neoprene cast of choroid viewed from without. The contrast between arteries and veins and the dense arborization in the choriocapillaris are well shown. Anterior region. × 28.

Flat Serial Sections of the Choroid:

Bleached choroid sections stained with Mallory's phosphotungstic haematoxylin.
Bleached choroid sections stained with Holmes's silver method.
Unbleached choroid sections stained with haematoxylin and eosin.
Unbleached choroid (Zenker fixation) sections stained with Mallory's phosphotungstic haematoxylin.
Unbleached choroid sections stained with Masson's trichrome stain.
Unbleached choroid sections stained with iron haematoxylin and Van Gieson.

Results and Discussion

While we were engaged on our investigation, Loewenstein (1949a, b) reported the presence of large, round polyhedric cells in the periphery of large and medium-sized choroidal arteries in the posterior choroid; they are 10–20 microns in diameter and have a central, round, dark nucleus, a clear cytoplasm, and a smooth cell membrane. He stated that these correspond to epithelioid muscle cells or glomus cells; the latter have been described as the basic elements of arterio-venous anastomoses, which he therefore believes must be present in the posterior segment of the human choroid. He regards these glomera as an essential part of the mechanism for the maintenance of the intra-ocular pressure. Curiously enough Loewenstein found the "choroidal glomus cells" more frequently in hypertensive cases than in normal eyes, and they were particularly abundant in a case of retrobulbar tumour. More recently Loewenstein's theory has been taken a stage further by Orbán (1951) and by Kiss and Orbán (1952), who described localized dilatations upon the tributaries of the vortex veins, which they termed "bulbiculi". By analogy with the work of Clara (1939), and reinforced by the findings of Loewenstein, these workers concluded that these "bulbiculi" are the sites of arterio-venous anastomoses and that the choroidal circulation is controlled through their agency.

As is well known, however, the choroid contains a profusion of cells which may vary in appearance according to the normality or morbidity of the tissue, the method of fixation, the stains employed, and the plane in which the sections are cut. Thus, before deciding upon the presence or absence of glomera in the choroid, one must first define the minimal requirements necessary to establish their existence beyond reasonable doubt. Essentially, a glomus consists of an afferent artery, the Sucquet-Hoyer canal or shunt, and an efferent vein.

The first requirement, therefore, is an arterio-venous anastomosis. The shunt is surrounded by *several layers* of small polyhedral, epithelium-like cells, uniform in size with a well-defined cell membrane and having central, rounded, darkly-staining nuclei 7–10 microns in diameter. They superficially resemble naevus cells and are intimately associated with non-medullated nerve fibres; through their contractility they control the blood flow through the shunt. The second requirement, therefore, is an agglomeration of these characteristic glomus cells around the arterio-venous anastomosis. These two aspects of the problem will be considered separately:

Arterio-Venous Anastomoses.—The widespread existence in the normal circulation of arterio-venous anastomoses, which, under certain conditions, serve to short-circuit the blood from arterioles to venules, has been known since the latter part of the 19th century.

They have been described in the skin of man and are particularly abundant in the fingers, toes, nose, and lips (Sucquet, 1862; Hoyer, 1877; Bourceret, 1885; Grosser,

1902), in the glomus coccygeum (Schumacher, 1908), in the corpora cavernosa of the penis (Hoyer, 1877), in the thyroid gland (Modell, 1933), in the kidney capsule (Geberg, 1885; Golubew, 1893), in the membrane of the gastro-intestinal tract (Spanner, 1931), and in the submucous layer of the human stomach (Barclay and Bentley, 1949; Barlow, 1951; Walder, 1952).

In animals, arterio-venous anastomoses have been found in the rabbit's ear and in the toes of birds (Grant, 1930; Grant and Bland, 1931; Hoyer, 1877), in the fingers and toes of mammals (Vastarini-Cresi, 1902), in the tongue (Brown, 1937) and sympathetic chain ganglia of the dog (Nonidez, 1942), in the posterior abdominal region in cats (Miller and Godfrey, 1917), and particularly large ones in the wings of bats (Grosser, 1902). The existence of anastomoses in the living animal was established by the work of Clark and Clark (1930; 1934a, b), who studied their structure and function in vascularized transparent rabbit-ear chambers.

The recognition of the importance of arterio-venous anastomoses, however, was due largely to the classical work of Masson (1924; 1927; 1935; 1937) and Masson and Géry (1927), who made a detailed study of anastomoses occurring in the pulp of the fingers and toes in man; he applied to these structures the term neuro-vascular glomus, and his observation that they may occasionally give rise to tumours stimulated great interest in them. Their histology has been studied in detail by Clara (1927, 1939) and by Masson (1937). Both authors describe epithelioid cells in the outer wall of the arterial segment, and it is believed that they are modified smooth muscle cells: stimulation of the non-medullated nerve fibres, which form a network around them, gives rise to vigorous contraction in the anastomotic wall which also shows an independent rhythmic contractility.

The function of arterio-venous anastomoses is not completely understood, but when dilated they clearly permit a large amount of blood to pass directly from artery to vein without passing through the capillaries, and it is obvious that the amount of blood which may be by-passed through the anastomosis is enormous as compared with the normal capillary flow. Those found in the skin appear to play a part in temperature control, as probably do those in the dog's tongue and the bat's wing, but it is difficult to assume a similar function for those situated elsewhere; Clark (1938) suggested that they may in fact serve no useful function, being merely an unfortunate type of reaction to special circulatory conditions. This view receives some support from his finding that the arterio-venous anastomoses were nearly twice as frequent in a rabbit-ear chamber subjected to sudden temperature changes and infection. In this connection it would be of great importance if they could be shown to develop in the choroid in some types of glaucoma; indeed Cristini (1950) suggests that a reduction in the capillary bed may lead to shunts between the afferent and larger efferent vessels of the choroid.

By the micro-dissection of our Neoprene casts of the *normal* choroid we have not yet succeeded in demonstrating vascular connections which could be interpreted as arterio-venous anastomoses; certainly there are no such shunts associated with the large and medium-sized choroidal arteries. Nor was there evidence of any such structures in the flat bulk preparations or serial sections, although, as already stated, we would not expect such techniques to reveal them. In a few cast preparations the injection was incomplete and the Neoprene was seen to be entirely confined to the arterial side of the circulation: a strong point against the existence of short-circuit connections within the normal choroidal vascular system.

Neoprene casts demonstrate perfectly the " bulbiculi " of the vortex veins

FIG. 5.—Red Neoprene cast of choroid viewed from without, showing tributaries of a vortex vein passing over and under the choroidal arteries. At the point of crossing the vein is flattened and distorted. These swellings correspond to the "bulbiculi" of Kiss and Orbán (1951). Anterior region. × 33.

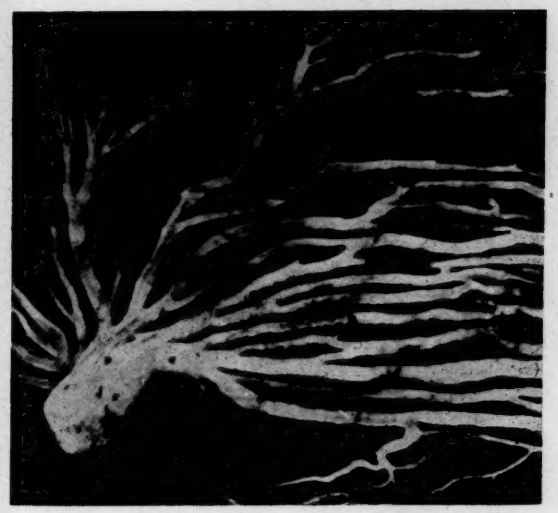

FIG. 6.—Neoprene cast of a vortex vein. Bulbous swellings may be seen on the venous tributaries, where they cross the horizontal artery seen above the mid-line. Anterior region. × 10.

(Fig. 5) described by Orbán (1951) and by Kiss and Orbán (1951), but dissection of the cast proves conclusively that there is no vascular channel connecting the artery and vein at this site. It can be stated with complete confidence, therefore, that these bulbous swellings do not represent arterio-venous anastomoses. They result from simple compression of the vein by the overlying artery, as the two vessels cross in the restricted space of the choroid, bounded by the intra-ocular pressure on the one side and the unyielding sclera on the other. This point will be readily appreciated by reference to Figs 5 and 6. An exactly similar distortion

FIG. 7.—Vessels seen in a rabbit-ear chamber. There is a bulbous swelling of the vein at the point where it is crossed and compressed by an artery. × 88.

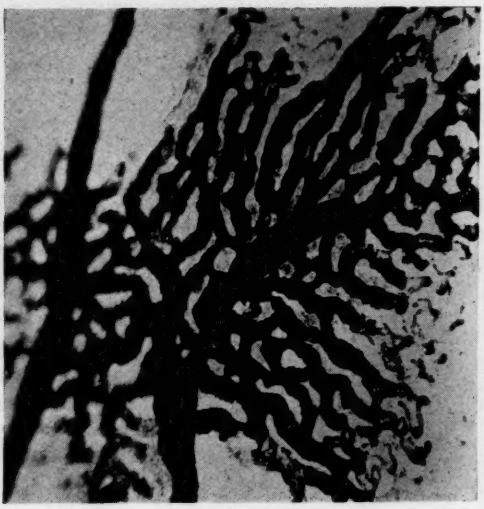

FIG. 8.—Neoprene cast of choroid showing a terminal arteriole. Note that the transition into capillaries is strikingly abrupt. Transmitted light. × 49.

of a vein by a traversing artery is seen in like circumstances in a vascularized rabbit-ear chamber (Fig. 7).

As one traces each minute vessel throughout the highly complex network in the choroidal cast, the absence of arterio-venous anastomoses becomes increasingly remarkable. Although the arterioles and venules intimately intertwine, there always appears to be a capillary subdivision, be it large or small, between their ultimate junction. There is, however, no gradual narrowing of the arterioles to capillary calibre as elsewhere in the body, for the transition into capillary subdivisions is unusually abrupt, as also is the formation of the venules (Fig. 8).

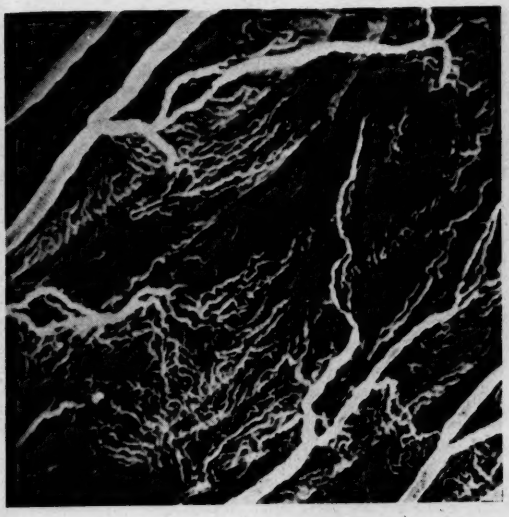

FIG. 9.—White Neoprene cast of choroid. Owing to partial filling Neoprene is largely confined to the arterial system. Note density of arterial anastomoses. Equatorial region. × 28.

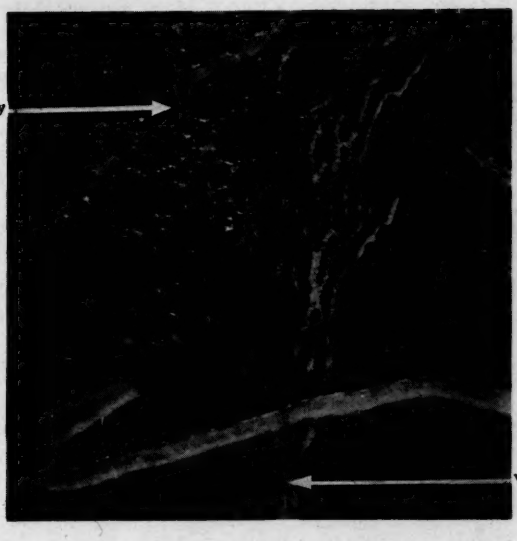

FIG. 10.—Red Neoprene cast of choroid. Note directness of capillary connections between artery and vein. Anterior region. ×50.

The directness of the capillary communications between arteries and between arteries and veins (Figs 9 and 10) is also a noteworthy point; one can easily imagine that atrophy of the capillary bed in disease might give rise to a compensatory dilatation of the remaining capillaries, with the formation of channels which would function in effect as arterio-venous shunts, thus producing a rise in venous pressure. Such a theory is purely speculative and must remain so until the opportunity arises of examining the choroid by this method, in cases of chronic glaucoma.

As will be readily appreciated on examination of these Neoprene casts, the choroidal vascular network is so exceedingly delicate and complicated that a detailed study of a sufficient number of specimens will take a considerable time.

We are not, therefore, at this stage of our investigation, prepared to state that arterio-venous anastomoses do not occur in the finest branches of the normal choroidal vasculature. Nevertheless, it can be stated that the only type of method likely to demonstrate them has so far failed to do so, and that there is no convincing evidence in the literature to warrant the assumption that they exist.

Choroidal Glomus Cells.—Turning now to consider the reported presence of glomus cells in the periphery of large and medium-sized choroidal arteries, our findings in the normal and pathological choroid will be discussed together.

It should be stated at the outset that horizontal and sagittal sections of some 500 eyes coming to the department for routine reporting, together with serial flat sections and bulk preparations stained by a variety of methods as already indicated, failed to reveal typical agglomerations of glomus cells in the walls of the choroidal arteries. Some preparations, however, show a number of different kinds of cells in relation to the arterial wall which may have been so described. Their characteristics and possible nature will be considered individually.

Ganglion Cells.—It has long been known that the ciliary nerves give off many finer branches, which subdivide into still finer plexuses in the inner layers of the suprachoroid and further on into the choroidal stroma, where they may consist of only a few or a single non-medullated fibre. On the nodal points of these plexuses and scattered along the course of the nerve branches, larger ganglion cells are interposed (Bietti, 1897; Salzmann, 1912). The fibres end in the choroidal vessels and presumably serve a vasomotor function. A typical choroidal ganglion cell is shown in Fig. 11. The significance of these cells in our present discussion is that they may occasionally be seen close to an arterial wall (Fig. 12), and it is important to bear their existence in mind when studying cells in relation to the circulatory system.

FIG. 11.—Choroidal ganglion cell situated at a nodal point in a fine nervous plexus. Flat section of choroid. Holmes's silver ×330.

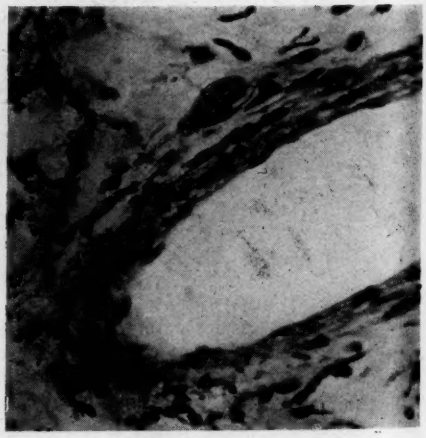

FIG. 12.—Ganglion cells situated in close relation to an arterial wall. Flat section of choroid. Haematoxylin and eosin. × 330.

Although ganglion cells are considerably larger than glomus cells, being about 20 microns in diameter, they very closely resemble the large clear cells depicted by Loewenstein in his photomicrographs, but they differ in possessing a pale basophilic cytoplasm.

FIG. 13.—Large foamy endothelial cells in a choroidal arterial wall in a case of malignant hypertension. The average size of these cells is 18 microns. Haematoxylin and eosin. ×650.

Endothelial Cells.—In sections which cut the choroidal vessels obliquely, a normal endothelial cell may occasionally appear flat and present as a large clear cell with a pale nucleus in the vessel wall; if it is borne in mind, this unusual appearance will create little difficulty. In malignant hypertension and atherosclerosis, however, the endothelial cells may undergo fatty degeneration and appear as large foamy cells in the vessel wall (Fig. 13). Loewenstein pointed out that these cells may be confused with the glomus cells he described, but it is to be remembered that his cells also had an increased frequency in hypertension and atheroma, and that his differentiation was based almost entirely upon the granularity of the cytoplasm. He states that fat staining makes the differentiation complete, but he does not say whether this investigation was, in fact, carried out. Indeed, it would be necessary to cut frozen or carbowax sections for such a purpose, and it would be impossible to ascertain whether or not the cells he depicts in dehydrated material originally contained fat.

In any event, the normal flat endothelial cell, the endothelial cell undergoing fatty degeneration, and the cells which Loewenstein has demonstrated in his photomicrographs, do not, in our opinion resemble glomus cells.

Smooth Muscle Cells.—As elsewhere in the body, the tunica media of the small arteries of the choroid consists of fusiform smooth muscle cells which are always orientated transversely to the length of the vessel, so that in longitudinal or oblique sections they appear as round cells, which, according to the site of section through the spindle shaped cell, will appear large and nucleated or small and non-enucleated. In the choroid, these muscle cells when cut transversely, that is in a longitudinal section of the artery, show a particularly ample cytoplasm. They appear to be somewhat fatter cells than are general elsewhere, and this feature is particularly noteworthy in the posterior choroid (Figs 14 and 15, overleaf) because the arteries are larger here and have a thicker muscular coat; indeed, they are even more obvious and numerous in the ciliary arteries. We believe that these are the cells which Loewenstein has demonstrated in his drawings; they differ, however, from his description in that their average size is only 7–10 microns, whereas he speaks of 10–20 microns, but there may have been some confusion between these cells and the endothelial type of cell seen in transverse sections of the artery.

More recently, similar cells have been noted by Sautter (1952) in the central artery in the region of the lamina cribrosa, and he compares them with those described by Loewenstein and also concludes that they are glomus cells. Schumacher (1938) reported that he had found epithelioid muscle cells aparts from anastomotic vessels in the small arteries of several organs, namely in the vasa efferentia of the glomeruli of the kidney and in the small arteries of the thyroid.

FIG. 14.—Normal choroidal artery showing smooth muscle cells, cut transversely, in the vessel wall. Their average size is 7–10 microns. Flat section of choroid. Haematoxylin and eosin. × 380.

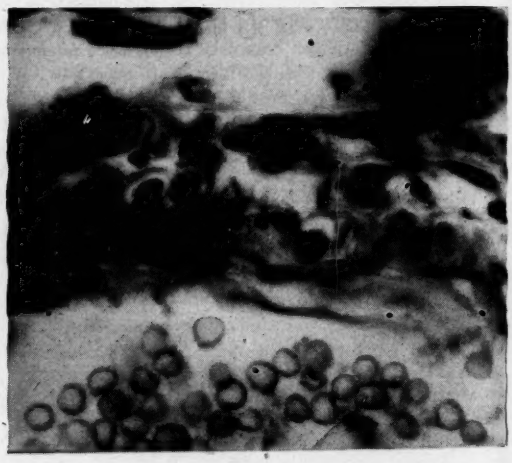

FIG. 15.—High-power view of Fig. 14. Note ample cytoplasm and well-defined cell margins. Haematoxylin and eosin. × 800.

As has already been stated briefly, it is generally agreed among those who have particularly studied the normal glomus, that the cells investing the anastomosis derive from typical smooth muscle cells and pass through a series of transitional forms to reach the characteristic epithelioid or glomus cell, which is the final stage of the process. Murray and Stout (1942) have drawn an analogy between this transition and the cellular investiture of capillaries seen in various organs, as described by Zimmerman (1923), and they have advanced strong evidence that these epithelioid cells are in fact identical with Zimmerman's capillary pericytes. It is known that such cells occur throughout the vascular system, even where no arterio-venous shunts have been found, and, as Murray and Stout have stated, this offers a satisfactory explanation for the occurrence of glomus tumours in the absence of normal glomera.

If we are correct in assuming that Loewenstein has described these large smooth muscle cells, then there is a certain amount of evidence, as indicated above, to support his contention that they may be of the nature of glomus cells. Since, however, the vasomotor nerves terminate, as far as is known, in the ordinary smooth muscle cells, which must ultimately be responsible for the control of blood flow, it is difficult to see, in the present state of our knowledge, what greater significance these larger muscle cells could have, unless, together with an arterio-venous shunt, they form a special apparatus. The choroidal vessels may contain isolated cells or groups of cells which depend for their stimulation upon mechanical or circulating chemical factors rather than upon nervous impulses, but this is not what is generally understood by glomus cells.

In conclusion, therefore, it is felt that the term glomus cells is better reserved to denote those epithelioid cells found in association with arterio-venous anastomoses, and that, until such structures have been demonstrated, it is neither justifiable nor useful to apply the term to the smooth muscle cells of the arteries of the normal choroid.

Cells of Unknown Origin.—On rare occasions, in pathological conditions, large cells may be seen either in the walls of choroidal arteries or scattered sparsely throughout the uveal stroma. They are of striking appearance, having a clear-cut cell membrane, a round or oval nucleus, and an abundant, faintly granular, refractile cytoplasm. They usually appear singly but occasionally in groups, and they vary in size from 10 to 15 microns, in proportion to the amount of cytoplasm present.

Their exact origin has not yet been determined, but they appear to be degenerating cells and are generally associated with inflammatory or degenerative processes. Those shown in Figs 16 and 17 (overleaf) were found in the choroid in a case of central choroidal sclerosis with hypertension. They may be macrophages or plasma cells containing pathological muco-protein secretions, that is, they may be of the nature of Russell bodies, with which, indeed, they may sometimes be associated. A point in favour of this latter view is that the cytoplasm of some of these cells was found to stain positively with the periodic-acid-Schiff stain. Alternatively they may be degenerate muscle cells.

Another possible explanation, although a highly speculative one, is to be found in the work of Goormaghtigh and Grimson (1939) and Goormaghtigh (1939, 1940, 1942, 1943, 1944, 1945, and 1947), who described large afibrillar and granular cells in the juxta-glomerular apparatus and in the media of the pre-glomerular arterioles of the kidney; these acquire a glandular activity which is believed to be the source of the pressor substance in hypertension. These cells were never found in the renal arterioles unless there was hypertensive disease, a condition of anæmia, or serious liver damage. Dunihue and Candon (1940) confirmed the original observations of Goormaghtigh and suggested that they originate from smooth muscle cells. Although Goormaghtigh cells have not been described in the vessels of the eye, it is not improbable that these choroidal cells may be of the same or similar origin.

Their importance in our present investigation lies in the fact that they also very closely resemble the cells depicted in some of Loewenstein's photomicrographs. The fact that his cells occurred in hypertensive disease, and when a malignant growth pressed on the posterior portion of the sclera, is additional evidence of their possible identity.

The nature and origin of these cells require further investigation, but the fact that we have not found them in the normal eye indicates that they are probably not part of a physiological mechanism for the control of blood flow. Furthermore, since they are apparently pathological cells and only rarely occur in layers or large groups around vessels, it is justifiable to assume that they are not of the nature of glomus cells.

In describing these various cells and in attributing to them a glomus-like function, Loewenstein supported his argument by an analogy with the sphincteric contraction which he had described in the retinal and conjunctival vessels (Loewenstein, 1949b; 1951). A similar sphincteric action was postulated by Evans (1947) to

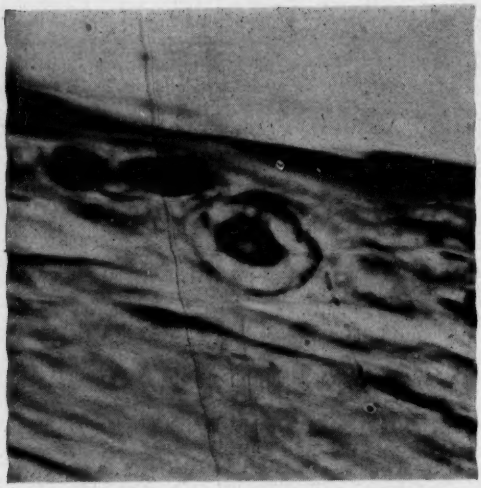

FIG. 16.—Cell of unknown origin in wall of choroidal artery. Note clear-cut cell membrane and refractile material in cytoplasm. Longitudinal section. Haematoxylin and eosin. × 1570.

FIG. 17.—Cell in choroidal artery wall similar to that shown in Fig. 16 but larger, due to a greater quantity of refractile material in cytoplasm. Flat section. Haematoxylin and eosin. × 1520.

explain the narrowing of vessel junctions which he noted in his *post-mortem* preparations of the retina and choroid. While these deductions may well be correct, for there is indirect pathological evidence to support them, it is to be remembered that one of the pitfalls of examining *post-mortem* material, whether in bulk preparations or in sections, is the misinterpretation of artefacts. In sectioning vessels which are as involved and tortuous as those of the choroid, one cannot accept a narrowing of the calibre as definite evidence of a constriction or spasm which existed in life, although it may have so arisen. Similarly, to point to narrowing of the vessel junctions as unequivocal evidence of sphincteric action in

a piece of *post-mortem* retina or conjunctiva, which has been fixed in formalin, cut radially, and mounted flat, is to be unmindful of the limitations of the technique. Indeed, in the case of the retina, it can be shown quite readily that when a *post-mortem* specimen is laid flat a pull is exerted on the vessel junctions where narrowing may then appear; furthermore, if the supporting tissue is partially destroyed by digestion, as may occur in *post-mortem* autolysis, these appearances may be further exaggerated (Fig. 18). While the theories of Evans and Loewenstein are most acceptable, their work is open to criticism on the above grounds and the correctness of their arguments still remains to be proved. Owing to the great difficulty of interpreting *post-mortem* appearances in terms of function, this confirmation is likely to emerge only through the examination of living tissues.

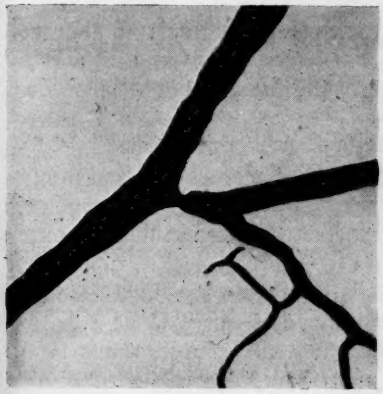

FIG. 18.—Retina injected with Indian Ink and partially digested. The tension, arising in a flat preparation of retina, is exerted at the vascular junction and the narrowing is thus due to artefact. Flat retina. × 95.

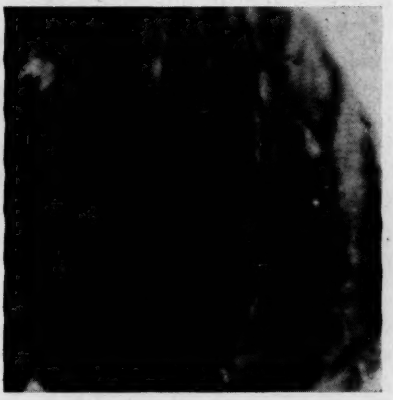

FIG. 19.—Choroidal circulation in a living rabbit as seen through a Perspex window in the sclera.

An attempt along these lines has recently been made in this department. Mr. Charles Cook has inserted small circular perspex windows into the sclera of living rabbits and thus, with a light source directed into the eye, it is possible to study the living choroidal circulation. The blood flow through the large vessel layer of the choroid can be readily seen, but the slight head movements of the anaesthetized animal make it difficult to obtain photographic records, which are an essential part of such a study. However, Fig. 19 gives an indication of the results obtained. So far we have not observed any evidence of shunt mechanisms or sphincteric action in the choroids of these animals.

In concluding this paper, it may be recalled that many of the difficulties still existing in our understanding of normal and pathological processes in the eye depend to a great extent for their ultimate elucidation upon an exact knowledge of its minute anatomy. After more than two centuries of careful

research it is remarkable that our information upon some of the essential points should remain so inadequate. It would appear that new techniques are necessary to obtain the accurate evidence required, for the gaps in our knowledge are not to be bridged by speculation. It is hoped, therefore, that the potentialities of these microscopical Neoprene casts when fully explored will help to provide some of the necessary information by which old theories may be tested and new ones constructed.

Summary

(1) A technique for preparing Neoprene casts of the choroidal vessels is described and the advantages of the method indicated.

(2) A detailed study of the choroidal vessels in the normal and abnormal subject is at present in progress at the Institute of Ophthalmology. The above technique, in conjunction with flat bulk preparations and flat serial sections of the choroid, together with observation of the choroid in the living animal, is being used. An account is given of the findings so far obtained.

(3) Other workers have reported the presence of glomus cells and arterio-venous anastomoses in the normal choroid. These findings have not been confirmed by our investigation and the evidence advanced in their reports is critically discussed.

(4) The proposition that arterio-venous anastomoses may develop in the choroidal circulation in pathological conditions is thought to be a feasible one. In at least some cases of glaucoma, these anastomoses might be the anatomical basis of the rise in ocular tension. The Neoprene cast technique should be of value in investigating the choroidal vessels in glaucoma, and the method will be utilized in future studies, when suitable material becomes available.

My thanks are due to Dr. Peter Hansell for the photomicrographs. I am particularly grateful to Mr. G. E. Knight and Mr. A. McNeil for technical assistance and to Miss E. FitzGerald for secretarial help.

REFERENCES

ASHTON, N. (1951). *British Journal of Ophthalmology*, **35**, 291.
——— (1952). *Ibid.*, **36**, 265.
BARCLAY, A. E., and BENTLEY, F. H. (1949). *Brit. J. Radiol.*, **22**, 62.
BARLOW, T. E. (1951). *J. Anat., Lond.*, **85**, 1.
BIETTI, A. (1897). *Ann. Ottal.*, **26**, 334.
BOURCERET, P. (1885). " Circulations locales l^e partie: La main ". Doin, Paris.
BROWN, M. E. (1937). *Anat. Rec.*, **69**, 287.
CLARA, M. (1927). *Ergebn. Anat. Entw-Gesch.*, **27**, 246.
——— (1939). " Die arterio-venösen Anastomosen ". Barth, Leipzig.
CLARK, E. R. (1938). *Physiol. Rev.*, **18**, 229.
——— and CLARK, E. L. (1930). *Anat. Rec.*, **45**, 211.
——— ——— (1934a). *Amer. J. Anat.*, **54**, 229.
——— ——— (1934b). *Ibid.*, **55**, 407.
CRISTINI, G. (1951). *XVI Conc. ophthal. 1950, Britannia Acta*, vol. 2, p. 865.
DUNIHUE, F. W., and CANDON, B. H. (1940). *Arch. Path.*, **29**, 777.
EVANS, J. N. (1947). *Arch. Ophthal., Chicago*, **37**, 182.
GEBERG, A. (1885). *Int. Mschr. Anat. Physiol.*, **2**, 223.
GOLUBEW, W. Z. (1893). *Ibid.*, **10**, 541.

GOORMAGHTIGH, N. (1939). *Proc. Soc. exp. Biol.*, **43**, 688.
——— (1940). *Amer. J. Path.*, **16**, 409.
——— (1942). *Bull. Acad. Méd. Belg.*, 6 sér., **7**, 194.
——— (1943). *Ibid.*, 6 sér., **8**, 502.
——— (1944). " La fonction endocrine des artérioles rénales ". Fonteyn, Louvain.
— ——— (1945). *J. Path. Bact.*, **57**, 392.
——— (1947). *Amer. J. Path.*, **23**, 513.
——— and GRIMSON, K. S. (1939). *Proc. Soc. exp. Biol.*, **42**, 227.
GRANT, R. T. (1930). *Heart*, **15**, 281.
——— and BLAND, E. F. (1931). *Ibid.*, **15**, 385.
GROSSER, O. (1902). *Arch. mikr. Anat.*, **60**, 191.
HOYER, H. (1877). *Ibid.*, **13**, 603.
KISS, F., and ORBÁN, T. (1951). *Acta Morph. Acad. Sci. Hung.*, **1**, 23.
LOEWENSTEIN, A. (1949a). *Nature, Lond.*, **163**, 69.
——— (1949b). *Amer. J. Ophthal.*, **32**, 1651.
——— (1951). *British Journal of Ophthalmology*, **35**, 595.
MASSON, P. (1924). *Lyon chir.*, **21**, 257.
——— (1927). *Arch. Sci. méd.*, **50**, 47.
——— (1935). *Bull. Soc. franç. Derm. Syph.*, **42**, 1174.
——— (1937). " Les glomus neuro-vasculaires ". Actualités sci. industr. No. 453: Histophysiologie IV. Hermann, Paris.
——— and GÉRY, L. (1927). *Ann. Anat. path. méd.-chir.*, **4**, 153.
MILLER, N., and GODFREY, J. S. (1917). *Anat. Rec.*, **13**, 177.
MODELL, W. (1933). *Ibid.*, **55**, 251.
MURRAY, M. R., and STOUT, A. P. (1942). *Amer. J. Path.*, **18**, 183.
NONIDEZ, J. F. (1942). *Anat. Rec.*, **82**, 593.
ORBÁN, T. (1951). *Szemészet Ophthal.*, **88**, 37.
SALZMANN, M. (1912). " The Anatomy and Histology of the Human Eyeball ", trans. E. V. L. Brown. Univ. of Chicago.
SAUTTER, H. (1951). *Ber. dtsch. ophthal. Ges. Heidelberg*, **57**, 103.
SCHUMACHER, S. VON (1908). *Arch. mikr. Anat.*, **71**, 58.
——— (1938). *Z. mikr.-anat. Forsch.*, **43**, 107.
SPANNER, R. (1931). *Anat. Anz.* **71**, *Suppl.* (*Verh. anat. Ges.*), **39**, p. 24–26.
SUCQUET, J. P. (1862). " D'une circulation dérivative dans les membres et dans la tête chez l'homme ". Delahaye, Paris.
VASTARINI-CRESI, G. (1902). *Monit. zool. ital.*, **13**, 136.
WALDER, D. N. (1952). *Clin. Sci.*, **11**, 59.
ZIMMERMANN, K. W. (1923). *Z. Anat. Entw-Gesch.*, **68**, 29.

Brit. J. Ophthal. (1952) **36**, 482.

HEXAMETHONIUM AND GLAUCOMA*

BY

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THIS investigation was undertaken in an endeavour to decide if the methonium ganglion blocking compounds could be administered to cases of vascular hypertension who were known to be suffering from glaucoma, or to similar vascular hypertensive cases of a glaucomatous disposition although this might not be known, without the danger of subsequent sequelae such as an increase in intra-ocular pressure.

The report by Ullman and Mossman (1950) of the occurrence of glaucoma in cases treated by the belladonna alkaloids administered orally, has raised the question as to whether or not similar dangerous side-effects might result from the administration of the alkamethonium ganglion-blocking agents in vascular hypertension. These authors state that the peripheral action of the alkaloids of belladonna is on the autonomic effector cells and not on nerve endings, producing in the eye (*i*) mydriasis, (*ii*) cycloplegia, and perhaps (*iii*) vasodilatation.

This may elevate the intra-ocular pressure in the following way:

(*i*) by the mydriasis narrowing the filtration angle,
(*ii*) by the paresis of the ciliary muscle abolishing the pull on the radial fibres of the scleral spur with loss of pumping action,
(*iii*) by the vasodilatation leading to a general vascular stasis.

Since pentamethonium and hexamethonium and their similar compounds—now known as the methonium halides—were first used for tentative clinical trial in vascular hypertension, it has been appreciated that, although they possess no true atropine-like activity, using this term in the pharmacological sense of a specific depressor of parasympathetic neuro-effector junctions, the parasympathetic ganglionic synapse depression which is part of their basic pharmacological response might give rise to the same end results as atropine, and produce in predisposed subjects a raised intra-ocular tension subsequent to mydriasis.

The six cases reported by Ullman and Mossman (1950) were receiving extract or tincture of belladonna for general systemic disorders, such as gastric or duodenal ulcer, colitis, hyperacidity, etc., and the advent during such treatment of an ocular hypertension was a complication which had not hitherto been reported with the exception, perhaps, of a case (reported in

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1913 by Myashita and quoted by Duke-Elder, 1940) in which acute glaucoma followed the subcutaneous injection of atropine.

Although not an atropine-induced glaucoma, the following unpublished case (recently noted in S. Africa by A. G.) is also of considerable interest:

A female, 75 years of age, who was being treated for hypertension by " Vegolysen " (hexamethonium) tablets administered orally, developed acute glaucoma necessitating operation. This occurred after increasing the dosage of the methonium compound to two tablets (0.25 g. each) three times a day, it having been noted that one tablet produced no effect on the blood pressure. The doctor concerned was of the opinion that glaucoma was a contraindication to the use of the drug, and at the time of administration there was absolutely no evidence of the possibility of this existing.

In the light of the findings of this investigation, this case is very difficult to explain, unless, perhaps, on the basis of coincidence. On the other hand, very many cases of glaucoma have been reported as resulting from the mydriasis subsequent to the local or topical use of atropine and its associates.

Davson and Matchett (1951) report that in the rabbit, section of the cervical sympathetic is sometimes followed by a marked rise in intra-ocular pressure, but there is no clinical evidence that this would occur following the removal of such sympathetic control as only one of the more widespread effects of hexamethonium. Indeed, in the increasing clinical experience with hexamethonium, including in some cases the administration for periods of upwards of 2 years, few untoward ocular effects have been reported, yet it would seem likely that since the clinical potentialities of these compounds were first reported by Organe, Paton, and Zaimis (1949) some cases of potential glaucoma must have been treated for vascular hypertension and other conditions.

Many reports are now available of the findings in series of cases of vascular hypertension after carefully checked and supervised courses of treatment with the various methonium compounds. Burt and Graham (1950) investigating the effect of (C.6) hexamethonium iodide and (C.5) pentamethonium iodide in peripheral vascular disease and hypertension, noted *inter alia* that the pupils became slightly dilated in all of 27 cases (no further details of this visual change being given), that two cases showed transient loss of accommodation, and that the peripheral retinal vessels beyond the second division appeared dilated. Kay and Smith (1950), investigating the effects of these compounds on gastric secretion, note among the side-effects only a suffusion of the conjunctiva as an almost constant finding discernible within a few minutes of intramuscular injection. Campbell and Robertson (1950), reporting treatment by hexamethonium bromide of eight cases of severe hypertension with papilloedema, note among side-effects a blurring of vision which occurred in every case from the beginning of treatment, but unfortunately there is no ophthalmic report on the cause of this or even if it referred only to the use of the eyes in close work.

Rycroft and Romanes (1952), discussing the use of these compounds together with postural ischaemia anaesthesia in ophthalmic surgery, state

that the intra-ocular pressure may fall so low that it fails to register with the Schiötz tonometer, and that the cornea may remain concave until manipulated back into the normal position.

In view of the reported effect of these compounds on ocular accommodation, Locket, Swann, and Grieve (1951), reporting on the use of pentamethonium bromide and hexamethonium bromide in 34 cases of essential hypertension, actually had the intra-ocular pressure checked before and after using the drug. The result indicated that the intra-ocular pressure did not change in any particular direction.

Barnett (1951), comparing the clinical results of pentamethonium and hexamethonium and the side-effects which resulted from the unselective action of these compounds in producing a generalized interruption of the autonomic nervous system, gives ophthalmic information of some importance: 12 cases of vascular hypertension equally divided into pentamethonium and hexamethonium groups showed in every case a fall of intra-ocular pressure.

Mackey and Shaw (1951), reporting a series of 15 cases treated by hexamethonium bromide administered orally, remarked in discussing parasympathetic effects that " almost all patients state that methonium therapy weakens the power of accommodation so that it may be difficult, for example, to read a newspaper ". Later, in referring to changes in the " eye grounds ", it is stated that no conclusion could be drawn regarding the degree of hypertension necessary to reverse retinopathy.

Turner (1951), in reporting on current therapeutics in the methonium compounds, states that after their use blurring of vision from paresis of accommodation is common and may be persistent.

Material

Eighteen patients in all were investigated while in-patients; of these seventeen were known cases of glaucoma and the eighteenth was a control. The cases of glaucoma were divided into two unequal groups:

(*i*) acute and sub-acute,
(*ii*) chronic simple.

It was considered that vascular hypertensives of unknown ocular history, but who were of a glaucomatous predisposition, would be most likely to fall into this latter and larger group.

Dosage and Method of Administration

The in-patient investigations were carried out in the recumbent position without a pillow. Restall and Smirk (1951) note that after hexamethonium bromide the blood pressure in the arm with the patient erect is usually lower than when he is horizontal. Estimations were made of the blood pressure; intra-ocular tension measured on the Schiötz tonometer; size of pupils measured by the pupillometer; power of accommodation checked against reading capabilities at a known distance; and charting of the visual fields for the presence, or absence, of defects. The

results are set out in Table I. As far as possible, this and all subsequent data in any given case were obtained by the same observer using the same methods and

TABLE I

Case No.	Age	Blood Pressure	Intra-ocular Pressure	Pupil Size (mm.)	Field Defects	Classification of Glaucoma	Clinical Comments
1	54	142/75	R. 25 L. 25	R. 5 L. 5	Markedly contracted	Chronic primary	—
2	75	175/100	R. 45 L. 38	R. 3 L. 3	Contracted	Bilateral chronic primary	R. and L. miotics (Fig. 1)
3	52	155/90	R. 25 L. 60	R. 4 L. 4	Minimal	Chronic	R. and L. miotics
4	63	134/95	R. 29 L. 72	R. 3 L. 3	Present	Simple chronic primary	R. and L. miotics
5	39	115/70	R. 38 L. 18	R. 4 L. 4	Sector contraction	Simple chronic primary	R. miotics L. trephine, draining well
6	75	188/99	R. 38 L. 38	R. 4 L. 5	Peripheral contraction	Chronic primary	(Fig. 2)
7	66	145/98	R. 27 L. 27	R. 4 L. 4	R. Bilateral arcuate scotoma L. Contracted to centre	Chronic primary	Circulatory insufficiency extra-systoles ++ (Fig. 3)
8	66	186/115	R. 28 L. –	R. 4 L. –	R. Contracted all round	Chronic primary	R. broad iridectomy, 1951. R. miotics L. enucleated, following haemorrhagic glaucoma
9	56	195/100	R. 40 L. 40	R. 4 L. 4	Full	Chronic primary	—
10	77	125/60	R. 16 L. 16	R. 3 L. 3	Sector contraction	Bilateral chronic primary	R. cyclodialysis, 1949 R. miotics L. trephine, 1951
11	56	180/120	R. 20 L. 50	R. 5 L. 5	R. Contracted above L. Peripheral constriction to near centre	Bilateral chronic	R. trephine, 1949 L. trephine, 1949
12	58	138/88	R. 36 L. 26	R. 2 L. 2	None	Sub-acute primary	R. and L. miotics (Fig. 4)
13	68	165/85	R. 41 L. 33	R. 1.5 L. 1.5	Full	? Secondary	R. miotics
14	46	100/40	R. 54 L. 35	R. 2 L. 2	Full	R. Primary acute L. Chronic	R. and L. miotics R. anterior sclerotomy 1951
15	69	185/115	R. 65 L. 55	R. 2 L. 2	Sector contraction to near centre	Chronic primary	R. and L. miotics L. decompression, 1952
16	80	130/75	R. 25 L. 21	R. 3 L. 3	Peripheral contraction	Bilateral chronic	R. and L. miotics
17	50	165/58	R. 30 L. 25	R. 4 L. inactive	Full	Bilateral chronic primary	R. and L. miotics. No visible synechiae (Fig. 5)
18	28	126/70	R. 26 L. Active corneal ulceration	R. 5	Full	Non-glaucomatous	Under treatment for ulcerative keratitis

instruments. This was considered very important with regard to intra-ocular pressure because of the individual variation in the Schiötz tonometers, in some of which the norm is represented by a pressure of 18 mm. Hg while in others it is as high as 22 mm. Hg.

To minimize any individual idiosyncrasy to the drug and to observe any undue

side-effects each case was given an initial trial injection of 10 mg. hexamethonium bromide intramuscularly.

For the purpose of these investigations and to obviate over-lapping and accumulation, it was considered that it was sufficient to give one dose in 24 hours starting from 10 mg. and increasing to 20, 40, 60, 80, and 100. Locket, Swann, Grieve, and Player (1952) assessed the maximum excretion of the drug to be within 24 hours.

Where the state of the patient's intra-ocular tension called for the administration of miotics these were given and noted in the graphs. It was also noted where one or both eyes had been operated upon; this accounts for some of the very low intra-ocular pressure readings.

Any case which, after an injection, showed signs of distress or collapse (and this did occur several times) was quickly restored by raising the foot of the bed, and thereafter the drug was stopped.

In each case the blood pressure and intra-ocular pressure were taken:

(*i*) at the time of the injection,
(*ii*) 15–30 min. afterwards,
(*iii*) 1½–2 hrs afterwards.

The curves are accurate for the times of the injections and readings concerned but not necessarily for limits in between. To avoid confusion with the intra-ocular pressure curves only the systolic blood pressure curves are recorded.

On discharge from hospital each case continued under observation as an out-patient and was given two 25 mg. tablets hexamethonium bitartrate by mouth thrice daily. It was realized, of course, that the dose by mouth should be of the order of ten times that given by injection. Two patients whose cases were complicated by cardiac conditions and in whom such medication without supervision was considered unsafe, were exempted from this further treatment. Every seventh day the patients reported to the hospital to have their blood pressure and intra-ocular pressure noted. The results are discussed below.

Clinical Findings

It was soon apparent that pupillary changes and alterations in the power of accommodation were so inconstant and variable as to render further estimation valueless. These variations were caused by the fact that many patients were under miotics, and others were of such an age that little of their power of accommodation remained. Attention was therefore focused on the blood pressure and intra-ocular tension.

Case Reports.—The details of five patients considered to be representative of the eighteen examined, are described below. The accompanying graphs (Figs 1 to 5) exemplify the typical curve changes noted in the text.

(1) Case 2, aged 75.—*Bilateral Chronic Primary Glaucoma with Vascular Hypertension* (on miotics, Fig. 1, opposite).

Intra-ocular pressure fell 9 mm. after the initial dose of 10 mg. Pressure tended to rise again in the next 24 hrs but after the second injection there was a fall of 15 mm. A slight rise followed in each 24 hrs but with a greater fall after each injection. At the end of 5 days, the intra-ocular pressure was about 10 mm. less than at the beginning.

Systolic blood pressure fell an average of 25 mm. Hg after each injection.

Mean fall in intra-ocular pressure was 10 mm.

The fourth injection was omitted and neither the blood pressure nor the intra-ocular pressure fell noticeably.

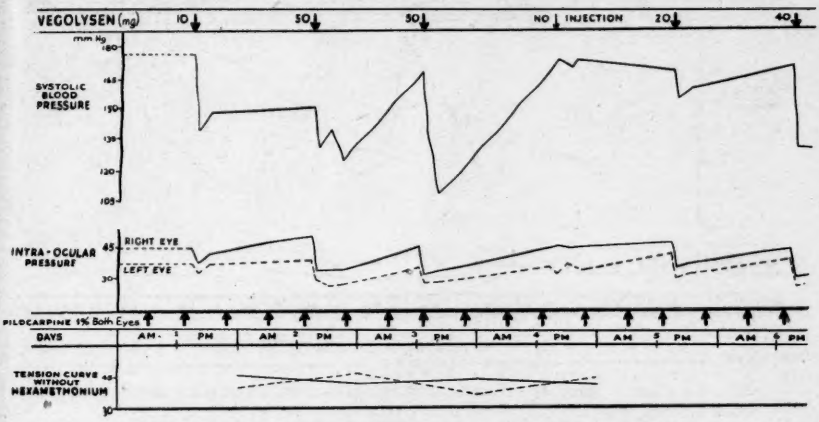

FIG. 1.—Case 2, aged, 75, bilateral chronic primary glaucoma.

(2) Case 6, aged 75.—*Chronic Primary Glaucoma with Vascular Hypertension.* (Fig. 2).

Intra-ocular pressure showed a marked drop after each injection with a very gradual tendency to rise prior to the next.

Systolic blood pressure on the whole seemed to fall steeply after each injection, but rose again relatively quickly.

Mean fall in intra-ocular pressure *c.* 10 mm.

After the fourth injection the blood pressure even tended to rise although the intra-ocular pressure tended to fall a little.

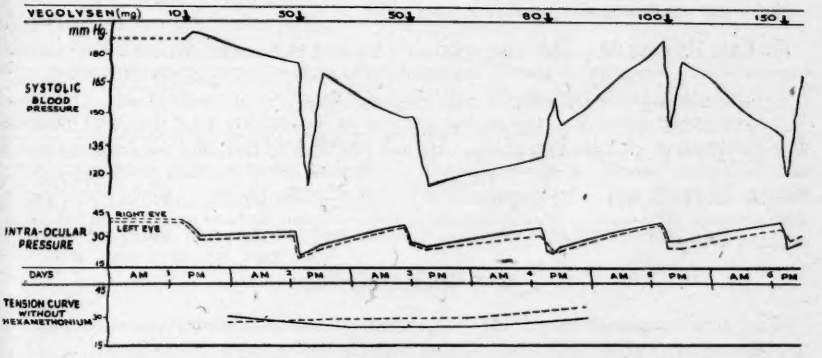

FIG. 2.—Case 6, aged 75, chronic primary glaucoma.

(3) Case 7, aged 66.—*Chronic Simple Glaucoma with Circulatory Insufficiency and Extra Systoles.* (Fig. 3, overleaf).

Intra-ocular pressure showed only a very slight variation in each eye after each injection, but that tended downwards. At the end of the investigation the reading was much the same as at the beginning and throughout the whole period the excursion was very limited.

Systolic blood pressure oscillations, very variable; prior to the fourth injection rose from about 140–190 to fall very steeply immediately afterwards.

A similar curve variation was not noticeable in the intra-ocular pressure readings.

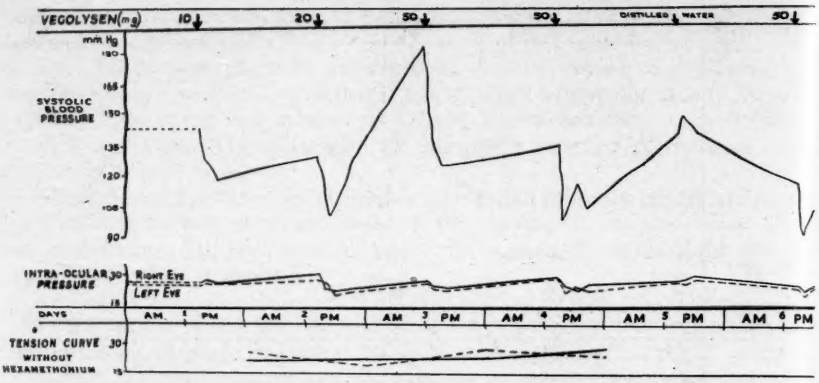

FIG. 3.—Case 7, aged 66, chronic primary glaucoma, circulatory insufficiency, extra-systoles + +.

(4) Case 12, aged 58.—*Sub-acute Congestive Glaucoma* (on miotics, thrice daily). This curve followed the pattern of the others. (Fig. 4, opposite).

Intra-ocular pressure diminished after each injection, with a very gradual return to normal in between.

Systolic blood pressure showed a considerable initial drop of 50 mm. Hg after the initial dose and this was maintained.

(5) Case 17, aged 50.—*Bilateral Chronic Primary Glaucoma* (on miotics, Fig. 5, opposite).

Intra-ocular pressure same as already noted.

Systolic blood pressure fell sharply.

Mean fall in intra-ocular pressure *c.* 10–12 mm.

(6) Case 18, aged 28.—This case, used as a control, had neither glaucoma nor vascular hypertension. No graph is shown, but the findings were of some general interest.

Intra-ocular pressure fell about 5 mm. after each injection and rose slowly in between.

Systolic blood pressure. The patient got out of bed quickly after the third injection and immediately felt faint and giddy. He was put back to bed, and the foot was raised and he quickly recovered, but meanwhile the systolic blood pressure rose very steeply between 30 and 40 mm. This happened again after a further injection and the investigation was stopped. The sudden rises in systolic pressure seemed to have no effect on his intra-ocular pressure.

Out-Patient Findings

The findings at the end of the period of oral treatment as out-patients are shown in Table II.

TABLE II

Case No.		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pre-investigation Intra-ocular Pressure	Right eye	25	45		39	38	38	27	28	40	20		36	41	
	Left eye	25	38		72	—	38	27	—	40	50		26	33	
Intra-ocular Pressure after Oral Treatment	Right eye	18	35		35	28	35	25	30	32	20		30	40	
	Left eye	20	29		55	—	35	25	—	34	45		28	35	

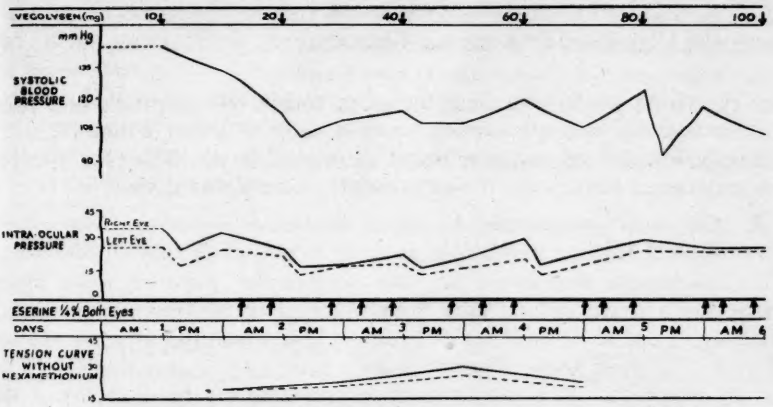

FIG. 4.—Case 12, aged 58, sub-acute congestive primary glaucoma. Right eye, no operation or field defect. Both eyes, eserine 0.25 per cent. thrice daily.

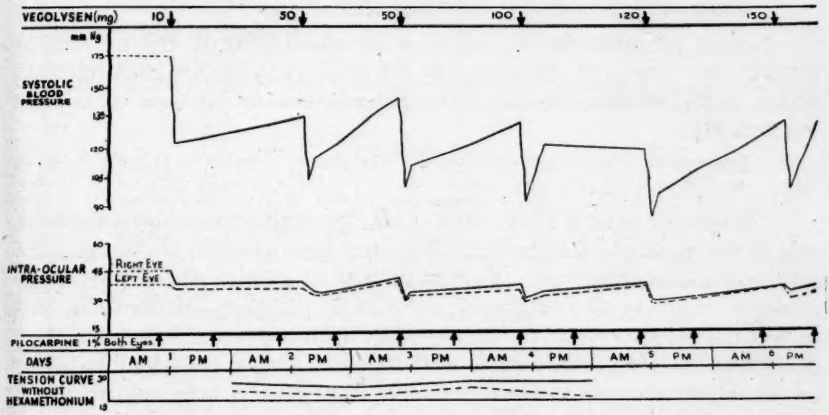

FIG. 5.—Case 17, aged 50, bilateral chronic primary glaucoma. Both eyes, pilocarpine 1 per cent. twice daily.

Side-Effects

The following side-effects were noted, but for more detail on this point papers relating to the use of the methonium compounds for vascular hypertension should be consulted.

Symptom	*No. of Cases*
Giddiness	1
Dry mouth	2
Malaise and pallor	3
Sweating	1
Temporary loss of sense of smell ...	1
Drug discontinued; Operation ...	2
No ill-effects	11

Conclusions

Cases with High Blood Pressure and Glaucoma:

A. Glaucoma not compensated (Cases 6 and 9):

The blood pressure in Case 6 showed some very steep falls and rises. The intra-ocular pressure curve showed a drop of about 8 mm. Hg after each injection and rose again to about its original level. This type of curve was maintained throughout the experiment. Case 9 was similar.

B. Glaucoma compensated by either miotics or operation (Cases 2, 8, 11, and 15):

Considerable fluctuation of the intra-ocular pressure took place. There was a sharp decline after each injection of hexamethonium and a tendency to rise prior to the next. Case 15, in which the subsequent rises reached dangerous levels but fell sharply after each succeeding injection, was an exception. This patient came to operation on the sixth day of the injections.

Cases with Low Blood Pressure and Glaucoma:

A. Glaucoma not compensated (Cases 1, 7, and 18):

Despite considerable fluctuations in the blood pressure, the intra-ocular tension kept very even, showing just the smallest falls after each injection and a slight tendency to rise, the changes were at no time more than 1–2 mm. Hg.

B. Glaucoma compensated by either miotics or operation (Cases 3, 4, 5, 10, 12, 13, 14, 16, and 17):

The general pattern of the intra-ocular pressure curve roughly followed that of the blood pressure curve, falling after each injection and rising again prior to the subsequent one. Case 14 showed a very high rise of intra-ocular pressure on one or two occasions, which fairly definitely followed rises and falls in the blood pressure curve. In most of the other cases the excursions in the intra-ocular pressure curve were minimal, despite considerable swings in the blood pressure curve (*e.g.*, Case 10.) Case 3 behaved peculiarly, showing very marked fluctuations between a low and a dangerously high intra-ocular pressure which followed the pattern of the blood pressure curve fairly closely.

It would seem that there is no clear-cut pattern for any given type of case, although it is, perhaps, suggestive that in the high blood pressure cases the oscillations in the intra-ocular pressure curve seemed greater than in those with low blood pressure, as if the balance of intra-ocular pressure maintenance was in some way upset.

In no case was a dangerous rise of intra-ocular tension produced immediately after an injection of hexamethonium, although eighty injections in all were given. This is, perhaps, of some significance when it is remembered that the duration of the action of the hexamethonium is short-lived.

On eleven occasions the drug was omitted and replaced by distilled water, and, as the graphs show, the falls which usually followed the injection were not so marked.

It would appear that the drug has little to offer in the treatment and and management of chronic glaucoma. It would also seem that there is little risk of a sudden or dangerous rise of intra-ocular tension when the drug is exhibited for therapeutic reasons.

Since this paper was written, four of the patients who had a relatively high intra-ocular pressure at the end of the investigation have come to operation.

Summary

(1) Increasing doses of hexamethonium bromide were administered intramuscularly to seventeen known cases of glaucoma under treatment in hospital.

(2) In no case was a rise in intra-ocular pressure noted after any injection. The general and consistent change in each case was a slight fall.

(3) On eleven occasions the hexamethonium was replaced by an injection of distilled water. It was then noticed that the usual fall in intra-ocular pressure was not so marked.

We wish to record our indebtedness to Dr. John Harper of the Medical Trials Unit, May and Baker, Ltd., for his willing help and for putting at our disposal adequate supplies of the compounds.

REFERENCES

BARNETT, A. J. (1951). *Lancet*, **1**, 1415.
BURT, C. G., and GRAHAM, A. J. P. (1950). *Brit. med. J.*, **1**, 455.
CAMPBELL, A., and ROBERTSON, E. (1950). *Ibid.*, **2**, 804.
DAVSON, H., and MATCHETT, P. A. (1951). *J. Physiol., Lond.*, **113**, 387.
DUKE-ELDER, W. S. (1940). "Text-book of Ophthalmology", vol. 3, p. 3340. Kimpton, London.
KAY, A. W., and SMITH, A. N. (1950). *Brit. med. J.*, **1**, 460.
LOCKET, S., SWANN, P. G., and GRIEVE, W. S. M. (1951). *Ibid.*, **1**, 778.
——— ——— ——— and PLAYER, H. P. (1952). *Ibid.*, **1**, 254.
MACKEY, W. A., and SHAW, G. B. (1951). *Ibid.*, **2**, 259.
MYASHITA (1914). Abs. from *Nippon Gankwa Zasshi*, April 1913, in *Klin. Mbl. Augenheilk.*, **52**, 561. *Quoted by* Duke-Elder, 1940.
ORGANE, G., PATON, W. D. M., and ZAIMIS, E. J. (1949). *Lancet*, **1**, 21.
RESTALL, P. A., and SMIRK, F. H. (1951). *Proc. Univ. Otago med. Sch.*, **29**, 10.
RYCROFT, B. W., and ROMANES, G. J. (1952). *British Journal of Ophthalmology*, **36**, 29.
TURNER, R. W. D. (1951). *Practitioner*, **167**, 541.
ULLMAN, E. V., and MOSSMAN, F. D. (1950). *Amer. J. Ophthal.*, **33**, 757.

Brit. J. Ophthal. (1952) 36, 492.

VITREOUS CYST WITH RETINITIS PIGMENTOSA.* A NEW SYNDROME?

BY

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THE clinical picture of a congenital vitreous cyst is highly exceptional. Cassady (1939) collected eighteen cases from the world literature. Unilateral retinitis pigmentosa is an equally infrequent disorder, of which Gordon (1949) was able to gather nineteen pure cases. Chance may play a very particular part, witness the fact that McLean (1933) was able to demonstrate one patient with unilateral retinitis pigmentosa followed by a second with a vitreous cyst. But when both these unusual clinical pictures appear in one patient and *a fortiori* in the same eye, one is strongly inclined to assume a relationship between these two conditions, either through one disorder being due to the other, or both resulting from the same cause. The following clinical observation may serve as a starting-point for our study.

Case Report

A 47-year-old woman consulted me on July 3, 1946, because of difficulties in reading, which could partly be attributed to an incipient presbyopia. The visual acuity in the right eye could be corrected with an error to 5/15 with S + 0.5, that in the left to 5/5 with S + 0.5. The anterior segment of the right eye showed no changes. In the lower nasal region the vitreous contained a semi-transparent, greenish, smooth, pear-shaped cyst, estimated to be about 5 mm. in length, which fluctuated freely in the vitreous, but which, as appeared from its unchangeable position in rest, had at one side a connection with the retina, not to be perceived by the investigator. No independent movements or changes in size could be observed. The right fundus presented the classical ophthalmoscopic findings of retinitis pigmentosa: a pale, slightly yellowish papilla, thin-walled vessels, and the characteristic trabeculate deposits of pigment in the surrounding peripheral areas (Fig. 1).

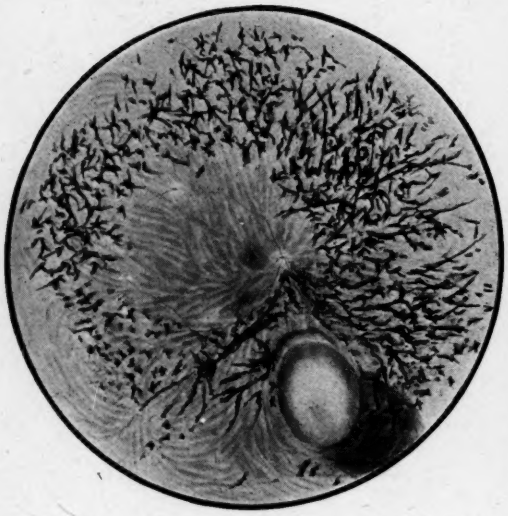

FIG. 1.—Fundus drawing of right eye.

Except for a small scar due to choroiditis in the temporal

* Received for publication April 7, 1952.

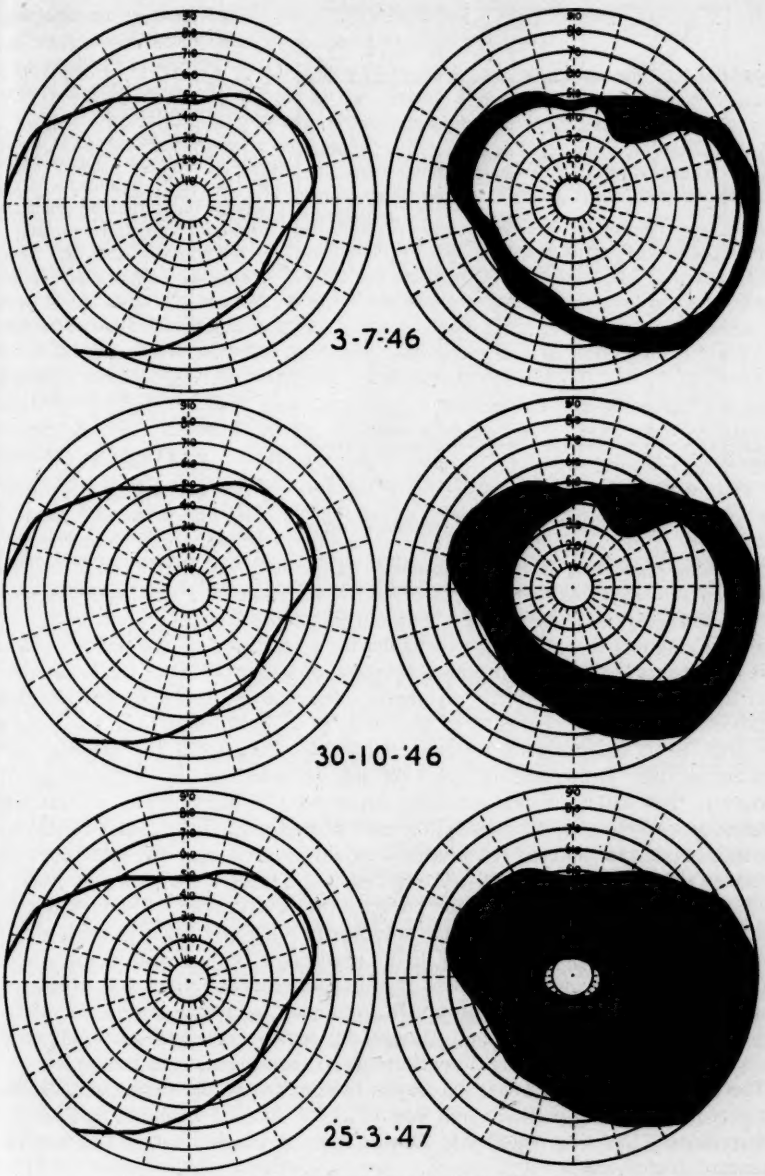

FIG. 2.—Progressive retrenchment of visual field in right eye.

region, the left eye was completely normal. The right field of vision (Fig. 2) showed a slight peripheral constriction, the left being unimpaired. The intra-ocular pressure was normal in both eyes.

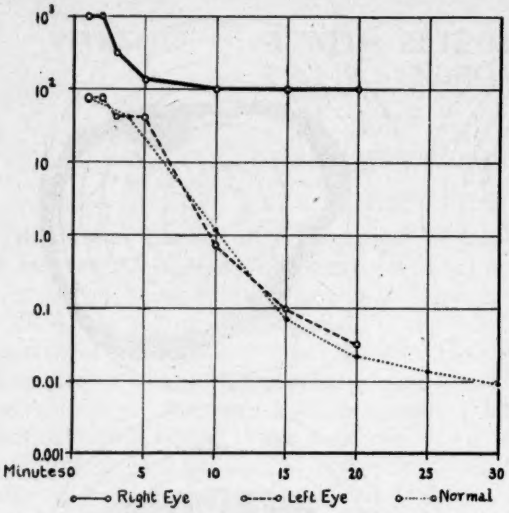

FIG. 3.—Dark-adaptation curves plotted logarithmically.

On October 30, 1946, the visual acuity in the right eye had decreased to 5/30, and the field of vision showed a concentric contraction.

On March 25, 1947, the field of vision had been reduced to 10°. The condition of the left eye had remained unaltered and continued to be normal.

A curve, obtained with Kentgens' apparatus at the Netherlands Ophthalmic Hospital, Utrecht, showed the dark adaptation of the right eye to be considerably impaired, whereas that of the left eye was normal (Fig. 3).

Diagnosis

In making a diagnosis I first had in mind a parasite, in particular a cysticercus, even a dead specimen. Mac Arthur (1934) has pointed out that, though the host shows a relatively satisfactory tolerance of living cysticerci, a dead specimen may have a markedly irritative effect. Thus the pigmentary degeneration of the eye might be assumed to have been due to the toxins secreted by the dead parasite. This is more or less consistent with the theory of Leber (1916) of the toxic origin of retinitis pigmentosa, with the pigmentary degeneration induced experimentally in laboratory animals by means of injections of sodium iodate into the vitreous (Sorsby, 1941), and with the retinal changes resulting from the presence of a cataractous lens dislocated in the vitreous, as described by Verhoeff (1931). However, this diagnosis was not supported by the haemogram, a maximum proportion of 5 per cent. of eosinophilic cells being found in the course of repeated determinations, so that an eosinophilia could not be said to have occurred. Toulant (1939) has shown that, although eosinophilia is a frequent symptom, its absence is not contradictory to the presence of a cysticercus. Casoni's test was negative in this patient, but this fact does not provide any negative evidence, for Cockburn (1946) reported a case of living cysticercus being found in the vitreous and while there was no doubt as to the diagnosis, eosinophilia was absent and Casoni's test was negative. I am myself, moreover, sceptical of this test, since it was evident that I personally had a markedly positive reaction, although, to my knowledge, I have never housed anything more than harmless ascarides.

The diagnosis was also unsatisfactory in other respects, for the patient's history suggested no starting-point. (The possibility of syphilis could be excluded, as Wassermann's test was negative.) During 5 years of observation the condition remained unchanged.

Similar Cases Previously Reported

Starting from the assumption that the cyst should not be regarded as parasitic in nature, I found in the literature two reports of cases which showed a striking

resemblance to my own findings, although the cysts occurred symmetrically in both eyes, and the retinitis pigmentosa was also bilateral:

(1) (Litinsky, 1931). A 24-year-old man presented bilateral, symmetrical, yellow-grey cysts, the size of a pea, localized in the vitreous and invisibly fixed, though relatively movable. The retinae showed the typical changes due to retinitis pigmentosa. The disturbances had been present for 2 years.

(2) (Perera, 1936). A 55-year-old man complaining of a recently impaired dark adaptation, presented two symmetrical cysts in the vitreous, and fundi showing the characteristic changes of retinitis pigmentosa.

Neither author ventures upon a sharply-defined diagnosis, although the parasitic origin of the cysts was rendered extremely unlikely by their bilateral character (cases of undoubted bilateral intra-ocular cysticerci being highly exceptional, of which more later on). Litinsky believed there was no causal relationship between the cysts and the pigmentary degeneration, and according to Perera the retinitis, or at any rate the degenerative tendency, was primary in nature.

In my opinion the case here reported, in which one eye presented the same changes as were encountered by Litinsky and Perera in both eyes, renders it extremely unlikely that the presence of a cyst in the one eye affected with retinitis pigmentosa is merely accidental. The combination of the unusually late development of the (if one insists) " symptomatic " retinitis pigmentosa, the speed with which the field of vision contracted, and, in particular, the unilateral appearance of the disease in the eye which also contained the cyst, practically proves the existence of a causal relationship between the various changes, as was also considered likely by Perera. This case thus constitutes an interesting addition to the reports of Litinsky and Perera.

Cases Combining Other Symptoms

A closer study of the literature on the simultaneous appearance of a pigmentary degeneration of the retina and cyst-like structures fixed to the retina or pedicled in the vitreous shows that the various examples may be classed as belonging more or less to this clinical picture.

(1) Waardenburg* (1929) reported a 33-year-old woman presenting the following changes:

Right eye, divergent strabismus and strabismus sursumvergens, slightly prominent. Vision limited to the lower temporal perception of hand-movements. Cornea showed no changes. Lens showed a foamy, rosette-shaped, pumice-like, complicated posterior cataract. Vitreous marked by a coarse fibrous structure with white junctions behind the lens. Fundus examination revealed a wax white papilla with fairly narrow arteries, and the entire fundus showed signs of pigmentary degeneration, white stria-like reflections, and streaks running towards certain fundus vessels. Peripheral areas presented typical bone cells, interspersed in places with coarser pigmentations and white atrophic lesions. In the lower temporal region there was a pear-shaped cystic white lesion, in the vicinity of large pigmented transverse bands and bone cells.

Left eye, showed no particular features, visual acuity 0.8, corrected with S — 0.5. According to Waardenburg the possibility of syphilis could be excluded.

(2) During the discussion which followed a lecture delivered by H. W. Scarlett, Hill (1929) reported having examined a middle-aged man, in whom he found a cyst in the vitreous of the right eye, with atrophic papillae and thin-walled retinal arteries in both eyes, the fields of vision showing a concentric contraction.

*I gladly take this opportunity of tendering my best thanks to my colleague P. J. Waardenburg for permission to use his findings in this paper.

(3) Lacarrère (1930) demonstrated a patient with bilateral cyst-like structures on the nasal halves of the papillae, the width of which was three-quarters that of the papillary diameter, associated with a retinitis pigmentosa. He regarded these cysts as a degeneration product resulting from the retinitis pigmentosa.

(4) Cassady (1939) described a case presenting a vitreous cyst in the right eye and membranes on both papillae; he advanced this theory regarding the possible cause:

> The associated prepapillary membrane in the case reported here suggests a remnant of the primitive epithelial papilla of Bergmeister, which forms the sheath of the hyaloid arteries and its branches. The presence of this membrane, the lack of pigment, and the location of the cyst in the centre of the vitreous suggest the primary vitreous as the site and origin of the cyst, as opposed to the theory previously advanced that the cyst probably originated from a degenerative adenomatous cyst of the vitreous processes.

(5) Viewed in this light, it may perhaps be doubted whether the diagnosis of a bilateral intra-ocular cysticercus in the case reported by Weve (1931)* was correct. This was the case of a 17-year-old girl, in whom a small cyst, about half the diameter of the pupil, was encountered in the meridian of 8 o'clock in the right eye, on a white halo, 1 to 1½ times the diameter of the pupil. A thickened band, leading to the vitreous, was seen to originate from the temporal region of the papilla. The left eye showed signs of optic neuritis. A semi-transparent cyst, twice as large, with a diameter of approximately 3 mm. and completely symmetrical to that in the right eye, was found at about 4 o'clock. Weve observed no retractions, and neither the contents nor portions of the cyst, which was treated with cauterization, could be examined.

In view of the striking resemblance of this case to that reported by Cassady, I think that it may not have been of parasitic origin, but should be classed with those discussed here.

It is difficult to establish criteria by which these cases may be judged, but certain morphological characteristics may be tentatively classified as follows:

Case	Author	Date	Retinal or Pedicled Vitreous Cyst		Papillary Cyst or Prepapillary Membrane		"Symptomatic" Retinitis Pigmentosa	
			Right	Left	Right	Left	Right	Left
1	Litinsky ...	1931	+	+			+	+
2	Perera ...	1936	+	+			+	+
3	Wagenaar ...	1948	+				+	
4	Waardenburg	1929	+				+	
5	Hill	1929	+				+	+
6	Lacarrère ...	1929			+	+	+	+
7	Cassady ...	1939	+		+	+		
8	Weve ...	1931	+	+	+	?		

The retinitis pigmentosa reported above is probably not essentially identical with the well-known, classical form. Since this small series includes two cases of unilateral pigmentary degeneration, it will be better to speak of a "symptomatic" retinitis pigmentosa, bearing in mind the remark of Joseph (1951) that

> unilateral retinitis pigmentosa is unrelated to the classical bilateral affection with its clear-cut genetic aspects and characteristic functional disturbances.

Thus it is obvious that the cases of bilateral pigmentary degeneration included

* The reports in the world literature regarding the bilateral appearance of an intra-ocular cysticercus should frequently be considered as doubtful, although a definite diagnosis might be made in exceptional cases. Lech Junior (1949) reports a few bilateral cases in a series of 111 patients with intra-ocular cysticercus.

above are essentially similar to the unilateral cases and may also be regarded as "symptomatic".

In addition to his own case and those published by Lacarrère and Litinsky, Perera (1936) mentions a case (reported by Vennin, 1910) of a 22-year-old man with a marked degree of myopia and bilateral pedicled cysts in the vitreous, but no impairment of vision or changes in the field of vision. Perera arrived at the following conclusions:

> The possible derivations of the cyst are as follows: the structure may arise from the foetal ocular cleft, mesodermal elements of the embryonic vitreous, or the hyaloid apparatus. It may be a dislocated cyst of the ciliary processes, a formed exudate into the vitreous, a product of retinal degeneration (including retinal cysts) or proliferation, or the result of degeneration of a parasitic cyst. The presence of myopia or pigmentary degeneration of the retina or of both these conditions in the four cases of bilateral cyst suggests a congenital degenerative aetiology.

Kraupa (1931) does not believe Litinsky's findings to be so exceptional and claims to have encountered vitreous cysts, mainly bilateral and occasionally associated with a retinitis pigmentosa, while the patients were frequently myopic (6–8D). As he does not supply further data, this material cannot be included in the Table, but it evokes the question whether the myopia should, in a certain sense, be regarded as the equivalent of "symptomatic" retinitis pigmentosa, and thus Perera is justified in including Vennin's case.

A New Syndrome?

In reporting these data it has been my intention to contribute to a provisional classification of this syndrome, which can gain in clarity only by the addition of new cases. It will not be possible to form a clearer idea of the aetiology, until a larger number of cases is published, for at present the opinions of the various authors are widely divergent.

The possibilities of treatment are outside the scope of this article, and it will not be possible to study them more closely until our knowledge of the aetiology has become clearer. It will then have to be decided whether Gördüren (1950) is correct in saying that:

> Cysts in the vitreous, apart from those of parasitic origin, provoke no irritation and therefore require no treatment.

Summary

A case of unilateral (symptomatic) retinitis pigmentosa, in which a cyst was found in the vitreous of the same eye is described.

By sifting and adding to the cases gathered from the world literature by Perera (1936) an effort has been made to achieve a provisional classification of a clinical picture, the aetiology and therapeutic possibilities of which can gain in clarity only by the addition of new cases.

More cases are probably known to investigators, but have been viewed hitherto from a different angle. I hope to have contributed to a more profound knowledge of a presumably independent syndrome.

REFERENCES

CASSADY, J. V. (1939). *Arch. Ophthal., Chicago*, **21**, 45.
COCKBURN, C. (1946). *British Journal of Ophthalmology*, **30**, 65.
GORDON, D. M. (1949). *Amer. J. Ophthal.*, **32**, 1350.
GÖRDÜREN, S. (1950). *British Journal of Ophthalmology*, **34**, 749.
HILL, E. (1929). *Trans. Amer. ophthal. Soc.*, **27**, 156.
JOSEPH, R. (1951). *British Journal of Ophthalmology*, **35**, 98.
KRAUPA, E. (1931). *Klin. Mbl. Augenheilk.*, **87**, 511.
LACARRÈRE, J. L. (1930). *Zbl. Ophthal.*, **22**, 776.
LEBER, T. (1916). *In* Graefe-Saemisch-Hess, "Handbuch der gesamten Augenheilkunde", 2nd ed., bd. VII, teil II, kap. 10A, p. 1076. Engelmann, Leipzig.
LECH, JNR. (1949). *Amer. J. Ophthal.*, **32**, 523.
LITINSKY, G. A. (1931). *Klin. Mbl. Augenheilk.*, **87**, 205.
MAC ARTHUR, W. P. (1934). *Trans. Roy. Soc. trop. Med. Hyg.*, **27**, 343.
MCLEAN, A. L. (1933). *Amer. J. Ophthal.*, **16**, 51.
PERERA, C. A. (1936). *Arch. Ophthal., Chicago*, **16**, 1015.
SORSBY, A. (1941). *British Journal of Ophthalmology*, **25**, 62.
TOULANT, P. (1939). *In* "Traité d'ophtalmologie", ed. P. Bailliart, C. Couteki, E. Redslob, and E. Velter, vol. 8, p. 717. Masson, Paris.
VENNIN (1910). *Lyon méd.*, **114**, 974.
VERHOEFF, F. H. (1931). *Arch. Ophthal., Chicago*, **5**, 392.
WAARDENBURG, P. J. (1929). Personal communication.
WEVE, H. (1931). *Klin. Mbl. Augenheilk.*, **87**, 597.

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CLINICAL METHOD OF OBSERVING CHANGES IN THE RATE OF FLOW OF AQUEOUS HUMOUR IN THE HUMAN EYE*†

II. IN GLAUCOMA

BY

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In a previous paper (Langley and MacDonald, 1952), the fluorescein instillation test was described and the results obtained in normal human eyes discussed. It was seen that the instillation of 10 per cent. fluorescein solution into the conjunctival sac resulted in the appearance of the dye in the aqueous humour, and that the concentration in the aqueous of normal eyes fell off slowly and evenly over a period of as long as 24 hours. The concentration was reduced by approximately 1 part per 100 million parts per hour. The level at any moment was held to represent a steady state between the concentration of fluorescein in the cornea and that in the aqueous, modified by the normal steady flow of aqueous; and this flow was responsible for the eventual disappearance of the dye from the anterior chamber. It was also emphasized that any sudden fall in fluorescein concentration indicated an increase in the rate of flow of aqueous, and that drainage of aqueous from the anterior chamber without its replacement by clear fluid would produce no change in the concentration.

In the present paper, the results in glaucomatous eyes are described, and the significance of these results in relation to certain of the known features of the disease is discussed.

METHOD.—The test was carried out as described in the previous paper. Miotic treatment, if used, was withheld for 24 hours before the test. The patient instilled the fluorescein drops himself either on rising on the morning of the test or before retiring the previous evening. In this way the concentration of fluorescein in the aqueous would have reached and passed its maximum before the observations commenced at 9.30 a.m. After a period of observation, a miotic (usually pilocarpine 1 per cent. or 2 per cent. and in some cases eserine $\frac{1}{4}$ per cent.) was instilled and further observations recorded. The fluorescein concentration was estimated by the method of Amsler and Huber (1946) and transposed into terms of actual concentration of the dye from the conversion curve shown in the previous paper. The ocular tension was taken at intervals with a Schiötz X-tonometer, pantocaine 1 per cent. anaesthesia being used for this purpose. Following the instillation of miotics the pupil in some eyes became so small that readings with the usual breadth of the beam of light became difficult, and it was found that when this occurred, the readings could be accurately checked by using the smallest aperture of the Haag-Streit slit lamp. Readings taken with the smallest beam were checked against those taken with the usual aperture in the calibrated apparatus, and were found to be consistently 0.1 amp. lower except in the highest ranges of fluorescein concentration.

* Received for publication May 7, 1952.

†Dedicated to Professor Lindner on the occasion of his 70th birthday.

Results

In Chronic Congestive Glaucoma.—Fifteen patients (29 eyes) were observed for 2 hours, after which pilocarpine 1 or 2 per cent. was instilled and further readings taken. Three eyes had been operated on and the results in these are reported separately below.

In nineteen eyes the tension was low and steady (between 20 and 25 mm. Hg Schiötz) and was associated with either a steady or slightly falling concentration of fluorescein in the aqueous during the initial period of observation.

In two eyes the tension was steady at a high level (68 mm. Hg Schiötz) and was also associated with a steady concentration of fluorescein.

In three eyes the tension was falling spontaneously, and in these the fluorescein concentration fell off at a rate greater than normal.

The two remaining eyes (both in the same subject) showed a falling fluorescein concentration occurring in a rising phase of tension.

The instillation of pilocarpine produced great changes in the concentration of fluorescein. In 24 eyes the concentration fell significantly, and in many cases dramatically, this change being accompanied by a fall of tension which in the majority amounted to only 3 or 4 mm. Hg. One patient arrived for the test with a tension of 68 mm. Hg in both eyes and a fluorescein reading of 2.5 ampères, which represents a level higher than is accounted for in our conversion curve.* In spite of repeated instillations of pilocarpine 2 per cent. and eserine 1 per cent. over 5 hours, the concentration remained steady at about this level and the tension remained high. Subsequently the tension fell to normal after admission to hospital, but we were unable to take readings during this fall. In this case, therefore, the high tension was associated with a relatively stagnant aqueous, as might be expected.

Many of the cases described above demonstrated such a great increase in the rate of flow of aqueous that the dye was completely washed out of the anterior chamber within an hour or so, and in some instances within less than 30 minutes (Fig. 1, see p. 501).

The increased flow of aqueous often manifested itself in an interesting way. Normally, the dye is seen in the anterior chamber in the form of a green flare extending from the back of the cornea to the lens capsule. In many cases this green flare became truncated so that it no longer extended as far back as the lens, and an optically empty zone appeared between the flare and the lens. In some instances the clear zone extended further forward than the mid-point between lens and cornea. A drawing of this phenomenon is reproduced in Fig. 2 (opposite). This effect is believed to be due to an excessive volume of aqueous entering the anterior chamber through the pupil and washing away the dye in its vicinity. The clear zone may remain so for an hour or more until the rate of flow of aqueous settles down, after which the dye again becomes homogeneously distributed.

* See Langley and MacDonald (1952), Fig. 1.

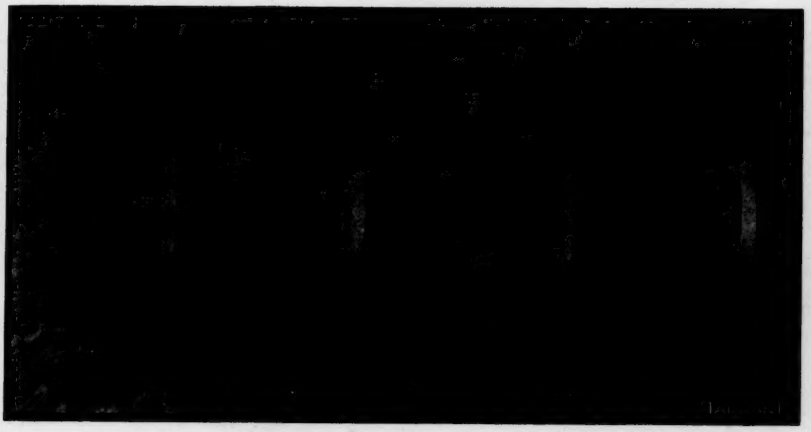

FIG. 2.—Case of glaucoma simplex.
(*a*) before pilocarpine.
(*b*) 30 minutes after instillation of pilocarpine.

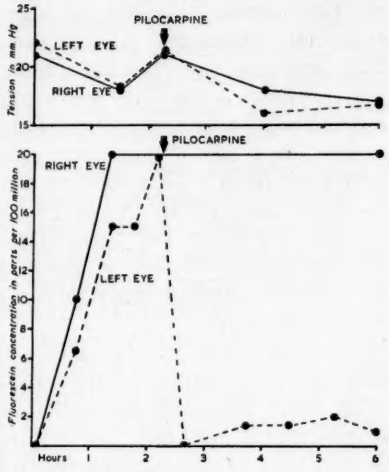

FIG. 1.—Case of chronic congestive glaucoma. Right eye trephined. Pilocarpine 2 per cent. instilled where indicated by arrow.

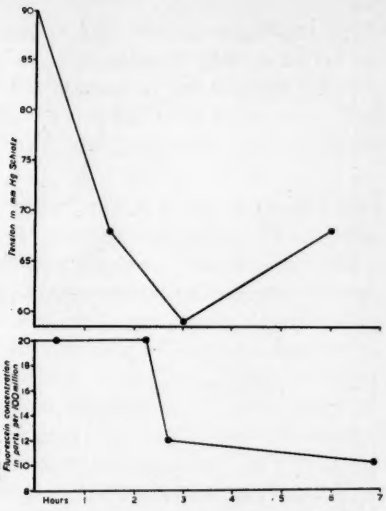

FIG. 3.—Case of advanced glaucoma simplex (right eye). A large fall in tension from a high level was not accompanied by any change in fluorescein concentration. The latter fell rapidly during a further drop in tension, and continued to fall off slowly during a subsequent rise.

IN GLAUCOMA SIMPLEX.—In 28 patients (56 eyes) examined, six eyes had been operated on. In the fifty non-operated eyes, it was found that, when the tension was steady or rising, the fluorescein concentration fell at approximately the normal rate. When a significant fall of tension occurred spontaneously, it was accompanied by an increased rate of fall in the fluorescein concentration. An exception to this occurs when the tension is particular high; here there may be a large spontaneous fall in tension to a level which is still well above normal, while the fluorescein concentration remains unaltered. Fig. 3 shows a spontaneous fall of tension from 90 mm. Hg to 68 mm. Hg, with the fluorescein level remaining steady. A further fall to 59 mm. Hg was accompanied by a fall in fluorescein concentration from 20 to 12 parts per 100 million. The tension subsequently rose again to 68 mm. Hg, and during this rise the rate of flow of aqueous slowed again as was indicated by the fact that fluorescein fell by only 2 parts per 100 million in 4 hours. This would appear to indicate that, in cases with a high tension, the circulation of aqueous through the anterior chamber is considerably retarded, but when the tension falls sufficiently the outflow of aqueous is allowed to proceed, and does so at a rate greater than normal.

The instillation of miotics again had a profound effect in the majority of cases. Thus in 47 out of the fifty non-operated eyes, the fluorescein concentration was reduced by 50 per cent. or more in less than an hour.

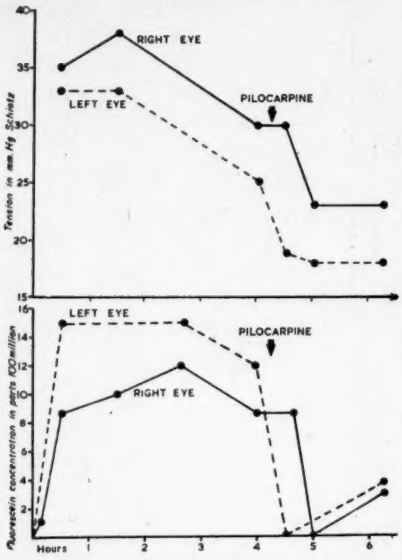

FIG. 4.—Case of bilateral glaucoma simplex. Pilocarpine 2 per cent. instilled where indicated by arrow caused a fall in tension and an increased flow of aqueous which washed the fluorescein out of the anterior chamber. Later the flow of aqueous slowed down, allowing more fluorescein to enter the aqueous from the cornea.

The dye was completely washed out of the anterior chamber in many eyes, and truncation of the green flare was observed in many others. Fig. 4 shows a case in which the instillation of pilocarpine 2 per cent. resulted in a fall of fluorescein concentration from a high level to zero in both eyes within 30 min., the tension falling at the same time. The subsequent slowing of the flow of aqueous allowed the fluorescein level to rise again.

Fig. 5 shows a case in which was seen the phenomenon of truncation of the flare. Following the instillation of pilocarpine 2 per cent., the reading in that part of the flare nearest the cornea was 6.5 parts per 100 million whereas that near the lens was zero. After a further 40 min., the dye again became evenly mixed, the reading throughout the whole depth of the anterior chamber being 7.5 parts per 100 million.

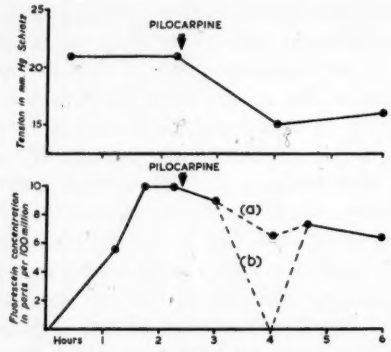

FIG. 5(*a*).

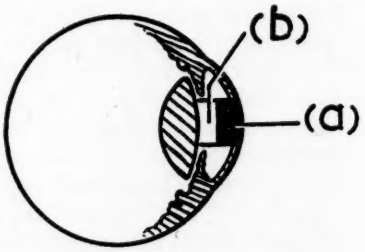

FIG. 5(*b*).

FIG. 5.—Eye in which truncation of the flare was observed. After the instillation of pilocarpine, the concentration of fluorescein near the lens (b) fell to zero, whereas that near the cornea (a) was less altered (see Fig. 5*b*). Subsequently the dye again became homogeneously mixed.

IN OPERATED EYES.—Three eyes had been operated on successfully for congestive glaucoma, one having been trephined and two having had a broad

iridectomy. The tension was low and steady and was accompanied by a steady fluorescein level. The instillation of pilocarpine produced no fall in the fluorescein concentration but caused the tension to fall slightly. These eyes therefore behaved in a manner similar to that of the normal eye. The results in a successfully operated eye (Fig. 1, right eye) may be compared with those in the fellow eye.

Six eyes had been operated on for glaucoma simplex, three of which could be regarded as clinically successful, the tension remaining below 25 mm. Hg over the 24 hours. Two of these eyes had been trephined and one had had a flap sclerotomy. The tension in the trephined eyes remained steady and the fluorescein concentration either fell off at the normal rate or remained unaltered even after pilocarpine or eserine was instilled. The other successful case showed a spontaneous drop in tension from 16 to 13 mm. Hg, this small change being accompanied by a large fall in the fluorescein level from 20 to 10 parts per 100 million in 2 hours. This case (Fig. 6) shows that although the operation had damped down the height and amplitude of the variations in tension, there still remained a tendency to spontaneous acceleration in the rate of flow of aqueous.

The three eyes in which the operation was clinically unsuccessful were interesting. One case had had a complete iridectomy, yet the tension still rose to 40 mm. Hg at times during the day. Miotics produced a marked fall in fluorescein concentration and a fall in tension. The second case (a flap sclerotomy) showed a rapid spontaneous fall in fluorescein concentration with a tension steady at 35 mm. Hg. A miotic was not used on this case. The third eye was one which had been trephined on two occasions because the first operation had not altered the height or variations in tension over the 24 hours. As the first trephine hole was blocked with iris tissue, the operation had been repeated at another site, and although the second trephine hole was gonioscopically patent and the overlying conjunctiva oedematous, the behaviour of the tension was again little altered. In this eye the fluorescein concentration fell during a rise in tension from 40 to 45 mm. Hg. A subsequent spontaneous fall to 30 mm. Hg was not accompanied by any further change in the fluorescein level. The results in this eye could be explained by a rapid flow of aqueous producing both a rise in tension and a fall in fluorescein concentration, the subsequent slowing down of the flow allowing the tension to fall and the fluorescein level to remain stationary.

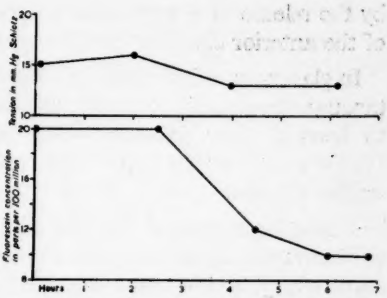

FIG. 6.—Spontaneous changes in an eye with glaucoma simplex which had been successfully operated upon. Fluorescein had been instilled 12 hrs previously. A large drop in the concentration of fluorescein accompanied a small change in tension.

It may be that in some cases of glaucoma the variations in tension are due to periods of increased formation of aqueous.

Discussion

Observations on aqueous veins have established that the outflow of aqueous in glaucomatous eyes is not constant but varies according to whether the tension is in a rising or falling phase (Thomassen, 1947; Thomassen, Perkins, and Dobree, 1950). These findings can be correlated with the results observed in the fluorescein instillation test. When the tension is in a rising phase, aqueous veins are often observed to fill with blood. In many of our cases in the same phase of tension, the flow of aqueous through the anterior chamber was retarded or proceeded at the normal rate. A falling phase of tension was usually accompanied by a more rapid flow of aqueous; in the same phase of tension, aqueous veins would be expected to be clear.

In some cases, however, it appeared that a rapid flow of aqueous may have been responsible for a rise in tension. In others, when the tension was very high, a fall was not accompanied by any demonstrable flow of aqueous. In such an event, a considerable fall in tension could be accomplished simply by the release of a very small volume of aqueous from the eye, the contents of the anterior chamber remaining relatively stagnant.

In glaucoma, miotics produce a great increase in the rate of flow of aqueous through the anterior chamber, and they are known to cause the aqueous veins to become clear (Ascher, 1942; Gartner, 1944). Thomassen and others (1950) confirmed the latter observation only if the miotic caused a fall of ocular tension.

It may be suggested that the miotic produces the sharp fall in fluorescein concentration by causing constriction of the pupil, thus presenting a larger surface area of iris tissue through which the dye could be absorbed. This possibility is discounted by our observations on glaucomatous eyes in which there was marked atrophy of the iris, or iridoschisis, or in which a large iridectomy had been performed. In addition, we were able to perform the test on a case of glaucoma with congenital aniridia in which the stump of the iris was diminutive and did not obstruct the broad chamber angle in any part. In all these cases, miotics produced the same effects as those seen in glaucomatous eyes with normal irides. Moreover, in those cases where truncation of the flare was visible, the dye could actually be seen to be displaced by the clear aqueous entering the anterior chamber through the pupil.

Miller (1952) reports that withdrawal of miotic treatment in cases of congestive glaucoma often reveals a lessened ability to compensate for a tendency to a rise in tension, whereas before the treatment was begun, the eyes had recovered spontaneously from innumerable minor congestive attacks over many years. To establish whether the effects of miotics were

related to previous miotic treatment, the results in twelve of our cases which had never been treated were compared with the remainder. In addition, four cases were investigated before and after a period of treatment. No significant differences were noted.

At this stage in this investigation, it cannot be decided whether the test will prove useful from the clinical point of view. Where a rapid flow of aqueous occurs spontaneously or is produced by the instillation of a miotic, the eye can be said to differ from the normal; and glaucoma is one condition in which such effects are found.

The test, however, does provide a means of studying some aspects of the hydrodynamics of the living glaucomatous eye, and further investigations may produce additional information.

SUMMARY

The results of the fluorescein instillation test in glaucomatous eyes are reported.

These eyes differ from the normal in that the rate of flow of aqueous does not remain steady, but undergoes fluctuations throughout the day which are reflected in the variations of ocular tension. Miotic drugs commonly produce a great increase in the rate of flow of aqueous with a simultaneous fall in tension.

An eye which has been operated on successfully for glaucoma usually shows responses similar to the normal eye, whereas in clinically unsuccessful operations the rate of flow of aqueous continues to vary spontaneously or can be made to do so by the instillation of a miotic.

REFERENCES

AMSLER, M., and HUBER, A. (1946). *Ophthalmologica, Basel*, **111**, 155.
ASCHER, K. W. (1942). *Amer. J. Ophthal.*, **25**, 1301.
——— and SPURGEON, W. M. (1949). *Ibid.*, **32**, June, pt. 2, p. 239.
GARTNER, S. (1944). *Arch. Ophthal., Chicago*, **32**, 464.
LANGLEY, D., and MACDONALD, R. K. (1952). *British Journal of Ophthalmology*, **36**, 432.
MILLER, S. J. H. (1952). *Ibid.* In the press.
THOMASSEN, T. L. (1947). *Acta Ophthal., Kbh.*, **25**, 221.
——— PERKINS, E. S., and DOBREE, J. H. (1950). *British Journal of Ophthalmology*, **34**, 221.

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OPTIC ATROPHY WITH ALTITUDINAL HEMIANOPIA IN NEUROFIBROMATOSIS*

BY

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INVOLVEMENT of the optic nerve in generalized neurofibromatosis is rare compared with affections of the peripheral and acoustic nerves. It may either show itself as a unilateral proptosis, loss of sight, and disk changes, as in a typical orbital tumour, or occur, without proptosis, as part of the "chiasmal syndrome" of Cushing. Although neurofibromatosis was first described by Smith (1849), and though it is now almost 80 years since the first recognition (Michel, 1873) that an optic-nerve tumour can occur in the disease, only about 55 reports of this are to be found in the literature so far. The case here described is therefore of unusual interest, although the description is necessarily only a clinical one.

FIG. 1.—Patient's appearance at examination.

Case Report

A single female housekeeper, aged 42, attended on May 25, 1951, with no complaint except a request for reading-glasses.

History.—Her left eye, she said, had been blind from birth. There had been no headaches nor vomiting. Recently she had had one large "semi-tumour" removed from the skin just beside the bridge of the nose (Fig. 1), and another from the side of her neck, because, she said, they had been getting noticeably larger during the last 2 years, although not painful. No biopsy had been made of these tumours.

Examination.—There was no proptosis, and no visible or palpable nodule or mass in the eyelids or orbits. Extra-ocular movements were normal. The left eye was divergent and quite blind. The pupils were equal and the right reacted to light and accommodation. Vision in the right eye was 6/12 partly and J 3 with correction. There was bilateral primary optic atrophy, more marked in the left eye. The retinal vessels were of normal calibre in the right eye, uniformly thinned in the left. The fundi were otherwise normal. Intra-ocular tension was 20 mm. Hg Schiötz in the right eye and 28 mm. in the left. Trans-illumination was clear. Slit-lamp examination of the anterior segments showed them to be normal.

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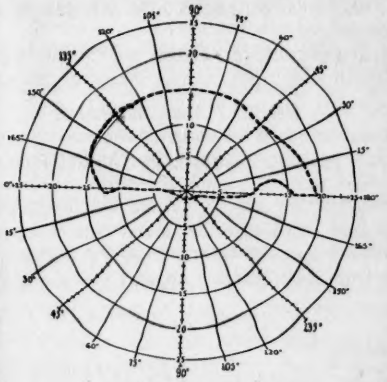

FIG. 2.—Field of vision of right eye.

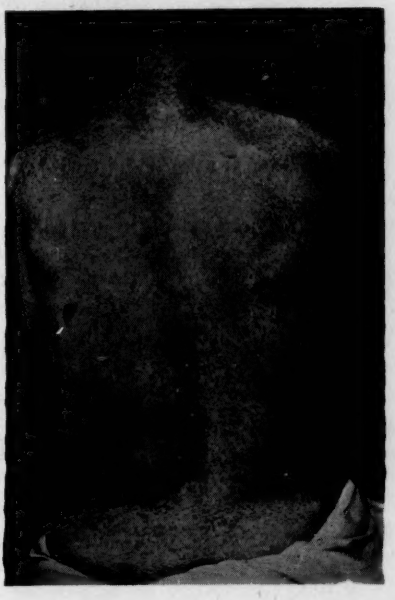

FIG. 3.—Appearance of skin on back and shoulders.

The field of vision of the right eye (Fig. 2) showed a clear-cut altitudinal hemianopia, with loss of the lower half of the field and sparing of the macula.

General Appearance.—The patient was small, five feet in height, and 7 st. 10 lb. in weight, but of normal build and physique. Her head was large for her size with a high forehead (the circumference being 23″ and occiput to nasion 14″): an *x* ray of the cranium, including the sella turcica, was normal. Distribution of axillary and pubic hair normal.

Skin.—This was deeply freckled all over the trunk and limbs and there were several large *café-au-lait* patches, the largest being on the right breast (3 × 1½″), on the mons, and on the right thigh (2″ diameter). There were several skin nodules on the back of the head and neck, and one on the back (Fig. 3), and some subcutaneous nodules on the course of the superficial nerves of the forearm. These changes had been present for as long as she could remember, had not progressed except for that on the nose mentioned above, and had never been painful.

Biopsy.—Pathological report on specimens excised from neck and forearm:
From forearm: firm, homogeneous white tissue, 1 × 0.5 cm.;
From back of neck: firm, rounded, homogenous white tissue, 1 × 0.5 cm.
Microscopy of both: neurofibroma.

Central Nervous System.—Apparently normal, except for a lower facial weakness on the left side, where the nasolabial fold was less marked (Fig. 1). The abdomen was rather flaccid and its upper reflexes not elicited.

Hearing.—Confirmed as normal by an otological colleague.

Heart and Chest.—Normal. Blood pressure 160/100.

Laboratory Investigations.—Urine analysis clear. Fluid intake and output records normal over several days. Glucose tolerance test normal.
No evidence of Cushing's syndrome.

Mantoux test faintly positive. Wassermann reaction and Kahn test negative both for blood and cerebrospinal fluid.

Blood count: haemoglobin 100 per cent., red blood corpuscles 5,000,000 per cmm., colour index 1.0, white blood corpuscles 4,500 per cmm.

Lumbar puncture: clear cerebrospinal fluid, at a pressure of 100 mm. with no alteration in its pressure from pressing the internal jugular vein; cells not in excess of normal, globulin-negative, protein 20 mg. per 100 ml.

Progress.—During the 10 months since she was first seen the patient's condition has remained unchanged. This is an undoubted case of neurofibromatosis, the manifestations of which probably showed in infancy, and have been stationary since, apart from the recent tumour growth on the face. The ocular complication may be caused by intracranial glioma of the optic nerves at the chiasmal region, or by pressure downwards on to the chiasm from a cerebral glioma. As her family live in different parts of the country, it has not been possible to interview them, but from their letters it appears that she is the only member affected.

Discussion

Neurofibromatosis is so diverse in its manifestations that it is small wonder that many medical text-books scarcely mention the eyes. The ocular complications are set out lucidly in the articles of François (1948) and Bloch (1948), who list three ways in which it may show itself:

(*i*) swellings on the eyelids, due to neurofibromata on the terminals of the fifth nerve, or in the orbit, due sometimes to tumours on the oculomotor nerves (Samuels, 1932), sometimes to an intra-orbital glioma of the optic nerve;

(*ii*) osseous manifestations, shown by absence of part of the orbital roof (Peyton and Simmons, 1946), so that proptosis, sometimes pulsating, can be produced, despite the fact that the optic disks are normal;

(*iii*) three kinds of intra-ocular effects:

(*a*) lesions in the mixed mesodermal-neurogenic tissue of the choroid, which can cause buphthalmos or glaucoma (Foster and Polson, 1934; Kreibig, 1949);

(*b*) retinal lesions, small isolated areas as described by Bloch (1948);

(*c*) effects on the optic disk: occasionally tumour formations, of which only a few cases have been reported (Goldsmith, 1949; Stallard, 1938); more often primary optic atrophy seen as an indication of glioma of the optic nerve, or papilloedema, due either to primary optic-nerve involvement (Stern, 1937), or to increased intracranial pressure where cerebral or eighth nerve lesions have existed (Gardner and Frazier, 1930; Penfield and Young, 1930).

A " central " form of neurofibromatosis is recognized by several writers, including Lichtenstein (1949), and Kinnier-Wilson (1940). It is even possible that most cases of glioma of the optic nerve, whether chiefly intra-orbital with proptosis, as in the cases of Gomes (1941, cited by Dresner and Montgomery, 1949), or intracranial with chiasmal involvement, are merely one sign of the disease. Lichtenstein (1949) says:

> The disease is so variable, however, that classification is virtually impossible, but certain important features must be recognized. In the universal form, cutaneous lesions, tumours in the central and peripheral nervous systems, and bony changes, are evident. In the classic form, cutaneous lesions and neurofibromata of the peripheral nerves occur with or without bony lesions. Careful study of the central

> nervous system in such instances, however, generally reveals microscopic evidence of the disease. In the central form no superficial evidence of disease may be discernible, that is, the skin may be free of pigmented patches of fibromata and the superficial nerves and nerve trunks may show no focal or diffuse thickenings. The nervous system, however, may show multiple intracranial or intraspinal foci of hyperplasia and neoplasia . . . Gliomata of the optic nerves, combined with spongio-blastomata of the brainstem, and other combinations are frequent.

Concerning changes in the field of vision, it is important to recognize that neurofibromatosis can be a cause of primary optic atrophy, without any proptosis, but with hemianopia and a normal sella turcica. Cushing (1930) specifically states that " glioma of the chiasm " is one of the causes of the chiasmal syndrome, and says that six out of his eighteen cases were associated with evidence of generalized neurofibromatosis. He also states that the field defects, though often bitemporal in character as in meningiomata or adenomata of the pituitary, are in gliomata of the chiasm " apt to be bizarre, and hemianopia with a vertical meridian is rare ". Davis (1940) says:

> gliomata which involve the chiasm and intracranial portion of the optic nerves are less common than the intra-orbital variety . . . exophthalmos is usually absent, at least for a time . . . changes in the visual fields in these cases are indispensable for diagnosis.

He points out that since *x*-ray evidence of disease within the sella turcica was not found in either of his cases, " each might have been passed over for an obscure case of atrophy of the optic nerve due to retrobulbar neuritis ", were it not for the " tell-tale signs " of neurofibromatosis. Martin and Cushing (1923) also say that " in such cases we have an explanation for some of the obscure cases of primary optic atrophy ". Indeed, it would appear from the literature that in all cases of optic atrophy of obscure origin it is advisable to examine both the patient and other members of the family for any signs of neurofibromatosis.

Besides the field changes, the case here recorded shows one striking feature; whereas many cases of optic-nerve glioma progress rapidly to a fatal conclusion, this eye condition appears to have been stationary for 30 or 40 years. Similar cases have, however, been recorded. Tikhomirov (1947) mentions a 35-year-old woman with neurofibromatosis developing bilateral optic atrophy, of which one side was probably of many years' duration. Davis (1940) describes a 26-year-old person (Case 5), with poor sight since early childhood, in whom a gliomatous tumour of the chiasm was found at operation. Davis also cites van der Hoeve (1925a, b, 1933) as having recorded a case (a woman aged 37 with neurofibromatosis who had had poor sight since childhood) in which intracranial operation revealed involvement of the optic nerve. Davis (1940) comments on the occasional slow progress of failure of vision in these cases of neurofibromatosis and quotes Martin and Cushing (1923) as stating that:

> one is forced to consider the possibility that there may be gliomas of different types—relatively malignant and relatively non-malignant varieties of what Hudson terms gliomatosis.

Summary

A case is reported of bilateral optic atrophy with altitudinal hemianopia in neurofibromatosis. The condition is probably quite stationary. The literature is reviewed.

REFERENCES

BLOCH, F. J. (1948). *Arch. Ophthal., Chicago*, **40**, 433.
CUSHING, H. (1930). *Ibid.*, **3**, 704.
DAVIS, F. A. (1940). *Ibid.*, **23**, 735, 957.
DRESNER, E., and MONTGOMERY, P. A. D. (1949). *Quart. J. Med.*, **18**, 93.
FOSTER, J., and POLSON, C. (1934). *Proc. roy. Soc. Med.*, **27**, 1124.
FRANÇOIS, J. (1948). *Ann. Oculist., Paris*, **181**, 753.
FULTON, F. J. (1929). *New Engl. J. Med.*, **200**, 1315.
GARDNER, W. J., and FRAZIER, C. H. (1930). *Arch. Neurol. Psychiat., Chicago*, **23**, 266.
GOLDSMITH, J. (1949). *Arch. Ophthal., Chicago*, **41**, 718.
GOMES, J. P. (1941). *Amer. J. Ophthal.*, **24**, 1144.
KREIBIG, W. (1949). *Klin. Mbl. Augenheilk.*, **114**, 428.
LICHTENSTEIN, B. W. (1949). *Arch. Neurol. Psychiat., Chicago*, **62**, 822.
MARTIN, P., and CUSHING, H. (1923). *Arch. Ophthal., N.Y.*, **52**, 209.
MICHEL (1873). *v. Graefes Arch. Ophthal.*, **19** (pt. 3), 145. *Cited by* Davis, 1940.
PENFIELD, W., and YOUNG, A. W. (1930). *Arch. Neurol. Psychiat., Chicago*, **23**, 320.
PEYTON, W. T., and SIMMONS, D. R. (1946). *Ibid.*, **55**, 248.
SAMUELS, B. (1932). *Arch. Ophthal., Chicago*, **7**, 868.
SMITH, R. W. (1849). "A Treatise on the Pathology, Diagnosis, and Treatment of Neuroma". Dublin. *Summarized by* Fulton (1929).
STALLARD, H. B. (1938). *British Journal of Ophthalmology*, **22**, 11.
STERN, R. O. (1937). *Proc. roy. Soc. Med.*, **30**, 1096.
TIKHOMIROV, P. E. (1947). *Vestnik Oftal.*, **26**, No. 4, p. 25.
VAN DER HOEVE, J. (1925a). *Amer. J. Ophthal.*, **8**, 101.
——— (1925b). *v. Graefes Arch. Ophthal.*, **115**, 355.
——— (1933). *J. belge Neurol. Psychiat.*, **33**, 752.
WILSON, S. A. KINNIER (1940). "Neurology", ed. A. N. Bruce. Arnold, London.

Brit. J. Ophthal. (1952) **36**, 511.

MEASUREMENT OF THE RESISTANCE TO THE AQUEOUS FLOW BY THE ELECTRONIC TONOMETER*

RESULTS IN CASES OF CONGESTIVE GLAUCOMA BEFORE AND AFTER TREATMENT

BY

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THE compression test performed with the electronic tonometer, combined with the use of Friedenwald's tables, makes it possible, to measure the resistance to the aqueous flow (Moses and Bruno, 1950; Grant, 1950; Prijot and Weekers, 1952).

In normal subjects, the coefficient of resistance varies from 2.9 to 7.3, the average being 4.5 (Prijot and Weekers, 1952).

We have measured the resistance to the aqueous flow in patients suffering from simple non-congestive glaucoma, before and after medical or surgical treatment. This part of our research, which has only recently been published (Prijot and Weekers, 1952a; Weekers and Prijot, 1952a, b, c), may be summarized as follows:

(*a*) In untreated non-congestive glaucoma, the resistance to the flow is usually increased, the increase being proportional to the degree of hypertension. The exact location of the pathological changes responsible for the increased resistance is still not known and subject to discussion (Ascher and Spurgeon, 1949; Goldmann, 1951; Thomassen, 1947; Weekers and Prijot, 1952a).

(*b*) The hypotensive action of pilocarpine in non-congestive glaucoma is essentially due to its reduction of the resistance to the aqueous flow (Ascher, 1942; Löhlein, 1950; Thomassen, Perkins, and Dobree, 1950; Grant, 1951; Prijot and Weekers, 1952b).

(*c*) Iridencleisis reduces resistance to the aqueous flow; this lessened resistance results either from fistulization or from improved aqueous flow through the natural channels (Weekers and Prijot, 1952c).

(*d*) On the other hand, retrociliary diathermy does not diminish resistance to the flow, and its hypotensive action is due to a decrease in the formation of the aqueous (Weekers and Prijot, 1952b).

The present paper relates our observations in congestive glaucoma. To avoid misunderstanding, we propose to define congestive glaucoma as follows:

We consider glaucoma to be congestive when the irido-corneal angle is completely closed during the hypertensive phase. The hypertension may be accompanied by a redness of the eye, but this inflammatory character is not constant and may be absent. The daily or periodic variations are often great. In congestive glaucoma, papillary excavation and perimetric defects result from intra-ocular hypertension.

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They are most evident when hypertension has been of high degree and of long duration.

These criteria of classification, which are similar to those adopted by Goldmann (1951) and Duke-Elder (1952), differentiate congestive glaucoma from the non-congestive condition; in the latter, the irido-corneal angle is either narrow or wide, but never closed. The three main symptoms (hypertension, papillary excavation, and perimetric defects) may progress independently of each other. There are also incomplete non-congestive glaucomas, glaucoma without hypertension being the most characteristic (Weekers, 1947).

Principle of the Compression Test

The compression test that we use is similar to that already proposed by Grant (1950). It has already been described (Prijot and Weekers, 1952a), but we shall briefly recall its principle.

Normally the ocular tension varies but slightly. This means that the volume of the liquid which penetrates the eye is equal to that which escapes during a given time. Placing a tonometer on the cornea changes this equilibrium; the foot of the tonometer raises the intra-ocular pressure and distends the sclera.

If the tonometer is kept in place for a prolonged period, the escape of fluid exceeds its formation and the intra-ocular pressure falls progressively. Several observations by Grant (1950) and ourselves (Prijot and Weekers, 1952a) demonstrate that the fall in tension is mainly due to a reduction in volume of the aqueous humour.

According to Goldmann (1951), the flow of the aqueous humour from the anterior segment of the eye obeys relatively simple laws. Poiseuille's law can be applied:

$$F = \frac{Pf}{R}$$

F is the flow of aqueous humour expressed in cmm. per minute. Pf is the outflow pressure of the aqueous humour, that is to say the intra-ocular pressure (Poc) minus the venous pressure at the point where the aqueous joins the blood (Pv). R is the resistance offered to the passage of the aqueous humour from the anterior chamber to the point where Pv is measured.

When the tonometer is placed on the globe, the pressure and the rate of flow of the aqueous are increased. In other researches we have shown that, on the contrary, the resistance remains constant (Prijot and Weekers, 1952a).

Friedenwald's tables (Moses and Bruno, 1950) permit calculation of the increase of Poc during the compression test. Tonometric pressure (Pt) is the pressure of the globe when the tonometer is placed on the cornea, Pt_1 is the tonometric pressure at the beginning of the test, and Pt_2 the tonometric pressure at the end of the test (*i.e.*, after 5 minutes). The average tonometric pressure during the course of the test is calculated accurately enough by the arithmetic mean:

$$\frac{Pt_1 + Pt_2}{2}$$

The average increase in pressure during the test is established by the formula:

$$\frac{Pt_1 + Pt_2}{2} - Poc$$

On the other hand, Friedenwald's tables (Grant, 1950) show the increase in the flow of the aqueous humour during the compression test.

V_1 is the reduction in volume of the globe at the beginning of the test, and V_2 the reduction in volume at the end of the test. Friedenwald's tables take into account the indentation of the cornea and retraction of the sclera.

The volume of liquid forced out of the globe during the test is $V_2 - V_1$. The quantity of liquid forced out per minute is:

$$\frac{V_2 - V_1}{5}$$

During the compression test:

$$R = \frac{Pf + \dfrac{Pt_1 + Pt_2}{2} - Poc}{F + \dfrac{V_2 - V_1}{5}}$$

Since R is not modified during the test, and since Poiseuille's law postulates that $R = \dfrac{Pf}{F}$,

$$R = \frac{\dfrac{Pt_1 + Pt_2}{2} - Poc}{\dfrac{V_2 - V_1}{5}}$$

Consequently the compression test performed with the electronic tonometer allows direct measurement of the resistance to the aqueous flow outside the globe.

Results

The coefficient of the resistance in normal subjects varies from 2.9 to 7.3, the average being 4.5.

In every case of congestive glaucoma, the compression test reveals a considerable increase in resistance *during the hypertensive phase* (Table I).

The measurement of the resistance in the fellow eye during the hypertensive phase of the glaucomatous eye reveals, in some cases, a marked increase of resistance without any pathological rise in tension. This seems to result from a consensual phenomenon.

The instillation of pilocarpine decreases the resistance providing it lowers the ocular tension (Table I).

TABLE I

Case No.	Eye	Date	Without Treatment		With Pilocarpine	
			Ocular Tension	Resistance	Ocular Tension	Resistance
1134/51	Left	20/3/51	36·8	32·2	—	—
		21/3/51	—	—	17·5	5·8
754/52	Right	20/2/52	—	—	8	3·4
		21/2/52	54	57	—	—
		26/2/52	—	—	11·9	4·4
		27/2/52	37·5	27	—	—
	Left	18/2/52	55·1	∞	—	—
		20/2/52	—	—	8	8·1
		21/2/52	54·1	67	—	—
1409/51	Right	16/4/51	55·9	22·7	—	—
		17/4/51	—	—	23·4	4·6
	Left	7/4/51	—	—	32·3	13·5
		16/4/51	63·8	18·7	—	—
		17/4/51	—	—	45·3	15·3
279/52	Left	19/1/52	46	28·7	—	—
2694/51	Left	6/7/51	58·9	∞	—	—
5641/48	Left	13/2/52	76	∞	—	—
		14/2/52	—	—	17·2	4·2
1875/51	Left	9/5/51	90	∞	—	—
1082/51	Left	19/3/51	60	90	—	—
		20/3/51	—	—	11·4	3·8
1084/51	Right	5/4/51	49·5	8·9	—	—
		6/4/51	—	—	16·7	6·7
		7/4/51	90	100	—	—
	Left	14/4/51	—	—	20·1	6·6

Decrease in resistance also follows iridencleisis. After the operation, the values of resistance and tension go through three stages:

(*a*) A few days after the operation, the resistance is greatly diminished and may even be below normal. At the same time the ocular tension is also below normal.

(*b*) In the weeks following the intervention, the resistance and the ocular tension both increase slightly to reach normal values.

(*c*) These conditions remain steady for months or even years (Table II, opposite).

The instillation of a miotic in the hypertensive eye or iridencleisis is likely

TABLE II

Case No.	Eye	Time since Iridencleisis	Ocular Tension	Resistance
342/41	Right	18 months	13·4	3·6
	Left	18 months	17·5	3·1
1134/51	Left	9 days	8·8	2·7
		20 days	10·8	3·3
		40 days	10·8	4·1
		70 days	11·1	5·1
4154/48	Left	3 years	19·7	5·9
754/52	Right	8 days	8	1·1
	Left	15 days	11·2	3·7
341/39	Left	3 years	22·5	4·8
6278/48	Left	3 years	14·2	4·7
1409/51	Right	7 days	10·4	3·3
		25 days	21·5	2·6
		35 days	17·5	10·8
		2 months	14·4	7·1
		4 months	16·7	8·1
	Left	7 days	9·4	4·8
		35 days	18·1	10·6
		2 months	14·7	11·4
		4 months	8·8	7·3
1557/33	Right	9 years	10·4	2·4
		9 years	8	2·9
1082/51	Right	3 years	12·2	4·6
		3 years	14	2·7
		3 years	10·8	4·4
		3 years	9·8	4·3
		3 years	12·4	2·9
	Left	7 days	10	1
		20 days	18·1	6·6
		35 days	16·9	8·1
		50 days	20·1	6·4
		3 months	18·1	7·5
		4 months	16·4	10·5
		5 months	18·1	4
		6 months	16·2	7·6
1668/51	Right	3 years	20·8	5
		3 years	14·7	4·5
		3 years	19·4	6·6
	Left	1 year	32·9	6·3
1084/51	Left	6 days	15	5·9
		50 days	13·2	14·4

continued overleaf

TABLE II—*continued*

Case No.	Eye	Time since Iridencleisis	Ocular Tension	Resistance
2694/51	Left	45 days 80 days	11·1 13·4	5·8 6
5641/48	Right	9 days	14·2	3·3
	Left	14 days	15·6	4·4
4082/51	Right	20 days	15·3	4·9
1875/51	Left	15 days 30 days	17 6·2	3·2 2·9

to reduce the resistance in the fellow eye when this is increased. In two cases where the fellow eye had presented a consensual raised resistance, acute glaucoma occurred and had to be treated surgically. The consensual increase of the resistance would therefore mean a predisposition to hypertension. This increase in the resistance without hypertension is asymptomatic. Only through the compression test can it be elicited.

Discussion

The researches of Grant (1950, 1951) and ourselves, with the electronic tonometer, show that most cases of ocular hypertension are due, totally or partially, to an increase of the resistance to the aqueous flow. Using another method, Goldmann (1951) reached the same conclusion.

The increase of the resistance to the aqueous flow exists in *chronic simple glaucoma* and in many forms of *secondary glaucoma*. This work shows that the pathological increase of the resistance is particularly marked in *congestive glaucoma*.

In congestive glaucoma, the increase of the resistance to the flow is generally and completely reversible, and is not therefore due to a permanent organic lesion. At first sight, one would be tempted to attribute it to the closure of the irido-corneal angle; in fact, during the hypertensive phase of congestive glaucoma, the angle is closed and the resistance raised. Between the crises, the resistance is normal and the angle, although often very narrow, is open. This explanation, however, is not entirely satisfactory, for we noted in certain cases that after the crisis, the resistance returned to normal whereas the angle remained apparently closed.

It seems to many workers as to ourselves, that the closure of the angle during the hypertensive phase in congestive glaucoma is not the primary phenomenon, but only the consequence of a uveal vascular phenomenon located in the anterior segment of the eye. This is the reason why we are inclined to attribute the changes in the resistance to some vascular disturbance. The presence of temporary consensual changes in the resistance of the fellow eye upholds this theory.

Pilocarpine greatly decreases the resistance to the flow. In congestive glaucoma, this miotic opens the irido-corneal angle but has also a vasodilator effect. Therefore it may act on the angle or on the anterior uveal vessels.

The action of iridencleisis presents an important and difficult problem (Weekers and Weekers, 1949). In congestive glaucoma, some days after the iridencleisis, the resistance and the ocular tension both fall below normal. At this time, the existence of a fistula* is obvious, but in the majority of cases this is only a passing phase. Some weeks later, the resistance and the ocular tension return to normal, and this contradicts the theory of a permanent fistulization. Actually, before the iridencleisis and between the hypertensive crises, the resistance to the flow is normal. Supposing that a permanent fistula existed after the operation, the compression test should reveal a permanent diminution of resistance, but, as we have shown*, this conclusion is not in accordance with the facts.

Summary

(1) The compression test performed with the electronic tonometer makes it possible to measure the resistance to the aqueous flow.

(2) This resistance is greatly increased in congestive glaucoma *during the hypertensive phase*. It is sometimes temporarily increased in the fellow eye, even though the tension in this eye remains normal. Between the hypertensive crises, the resistance to the flow is normal both in the glaucomatous and in the fellow eye.

(3) The instillation of pilocarpine restores the resistance to the flow to normal in cases where it restores a normal ocular tension.

(4) After iridencleisis, the resistance to the flow at first falls below normal then returns to normal.

* In a case of bilateral congestive glaucoma we performed an iridectomy on one eye and an iridencleisis on the other. Both operations restored the resistance and the tension to normal. The hypothesis of a fistulization cannot be applied to the iridectomy. In congestive glaucoma, it is possible that iridectomy and iridencleisis both restore the flow through the natural channels.

REFERENCES

ASCHER, K. W. (1942). *Amer. J. Ophthal.*, **25**, 1174.
——— and SPURGEON, W. M. (1949). *Ibid.*, **32**, June, Part 2, p. 239.
DUKE-ELDER, S. (1952). *Ibid.*, **35**, 1.
GOLDMANN, H. (1951). *Docum. ophthal., Den Haag*, **5-6**, 278.
GRANT, W. M. (1950). *Arch. Ophthal., Chicago*, **44**, 204.
——— (1951). *Ibid.*, **46**, 113.
LÖHLEIN, H. (1951). *Ber. dtsch. ophthal. Ges.*, **56**, 146.
MOSES, R. A., and BRUNO, M. (1950). *Amer. J. Ophthal.*, **33**, 389.
PRIJOT, E., and WEEKERS, R. (1952a). *Ophthalmologica, Basel*, **123**, 1.
——— ——— (1952b). *Ibid.*, **124**, 12.
THOMASSEN, T. L. (1947). *Acta ophthal., Kbh.*, **25**, 369.
——— PERKINS, E. S., and DOBREE, J. H. (1950). *British Journal of Ophthalmology*, **34**, 221.
WEEKERS, L., and WEEKERS, R. (1949). *Ophthalmologica, Basel*, **117**, 305.
WEEKERS, R. (1947). *Ann. Oculist., Paris*, **180**, 10.
——— and PRIJOT, E. (1952a). *Ophthalmologica, Basel*, **123**, 114.
——— ——— (1952b). *Ibid.*, **123**, 365.
——— ——— (1952c). *Ibid.* In the press.

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CYCLODIALYSIS COMBINED WITH POSTERIOR TREPHINING *†

BY

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IN the treatment of certain cases of glaucoma, most Dutch ophthalmologists are inclined to perform cyclodialysis, either in its original form as described by Heine or by the Blascovics method (cyclodialysis inversa). I now propose to discuss not the results of this operation, but its technique, which has never given me entire satisfaction. It is especially the necessary scleral incision, simple as it may appear, which I do not consider very easy to perform. If extreme caution is observed, the sclera may not be incised deep enough and it may therefore prove difficult to introduce a cyclodialysis spatula. In other cases, not only the sclera but also the choroid and retina may become perforated with consequent loss of vitreous. If, in such cases, a cyclodialysis spatula is introduced, it will not always move in the supra-choroidal space towards the limbus, but, before appearing in the angle of the anterior chamber, will penetrate through the ciliary body instead of tearing loose the sclera. I have therefore attempted to apply a different technique by substituting scleral trephining for scleral incision. This trephining is performed by means of a 1.5-mm. trephine under the insertion of one of the recti muscles (preferably the superior rectus, if it is desired to perform cyclodialysis in the upper area). The anterior part of the rectus muscle is exposed, a longitudinal incision is made, and both halves of the muscle are separated by sutures (see Figure). Thus a distinct triangle of the sclera becomes visible where trephining is performed.

Taking into consideration that the sclera is usually much thinner under the muscular insertion than elsewhere, I prefer for this purpose not Elliot's trephine but one which has a guard attached to it. The guard is set at a depth of 0.5 mm. which is in most cases quite sufficient. A scleral disk can thus be punched out whole without the use of scissors and without damage to the choroid. From the trephine opening onwards the ciliary body is torn loose in the usual manner. One should take care, however, to use a spatula which is somewhat longer than usual, the distance from the trephine hole to the limbus being about two millimetres greater. Apart from the technique, this procedure presents the following advantages:

The supra-choroidal and subconjunctival spaces are at once brought into communication with each other, and liquid can thus filter from the eyeball.

* Paper read to the Netherlands Ophthalmological Society, September, 1951.
† Received for publication June 5, 1952.

The insertion of the rectus muscle, which should be carefully replaced, prevents a prolapse of the choroid through the trephine opening. Furthermore, I assume (without being able to offer absolute proof—no eye thus operated on having as yet been dissected) that, owing to the movements of the rectus muscle, the trephine opening will less easily become obliterated, filtering from the eyeball being thus facilitated.

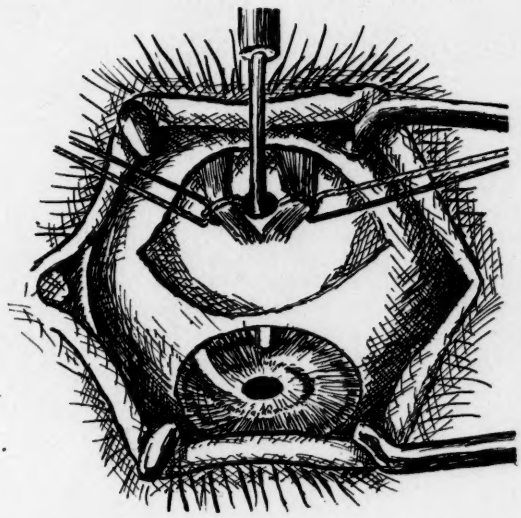

FIGURE.—Exposure of sclera by separation of rectus muscle, and insertion of trephine.

ADDENDUM.—After delivering the above paper, I came across an article by Sallmann (1935) entitled "Die Trepanationszyklodialyse, eine Abänderung der Heineschen Zyklodialysenoperation". It appears that Sallmann has also adopted a modified technique, for both practical and functional reasons. By Sallmann's method, however, the filtering hole between the supra-choroidal and subconjunctival spaces becomes obliterated quite quickly.

It remains to be seen what will be the final fate of a trephine hole situated beneath the rectus muscle. This can only be judged after my method has been used in a sufficiently large number of cases and has been tested both clinically and pathologically. As far as I know, Sallmann's method has hardly ever been applied in the Netherlands.

REFERENCE

SALLMANN, L. (1935). *Z. Augenheilk.*, **86**, 111.

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CASE NOTES

INSERTION OF SUPERIOR OBLIQUE WITH SUPERIOR RECTUS MUSCLE*

BY

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DUKE-ELDER (1949) quotes Heuck (1879) for evidence of insertion of the superior oblique muscle to the nasal side of the superior rectus. A case of this unusual abnormality is reported below.

Case Report

B. P., female, aged 14 years, admitted to the Worcester Eye Hospital on February 28, 1952, for operation to overcome congenital inaction of the right external rectus. There was no movement of the right eye beyond the mid-line when looking right but 5△ right hyperphoria was produced by the attempt. In the primary position there was no hyperphoria. Spectacles were worn for slight convergent strabismus.

Visual Acuity—Right: +4.00 D sph. +0.50 D cyl. axis 90°
Left: +4.50 D sph. +0.50 D cyl. axis 90°

The angle of squint, measured on the synoptophore, was only +6° with correction and +8° without.

It was planned to do what we have become accustomed to call a Temple Smith operation, but omitting recession of the internal rectus.

At operation, when the insertion of the superior rectus was exposed and freed from Tenon's capsule, a strong round cord of tissue about 3 mm. in diameter was found on the nasal side of the rectus muscle approaching it at an acute angle and disappearing beneath the nasal edge of the muscle to be inserted with it. The cord was white and glistening, being covered with a capsule. It was neither adherent to, nor fused with the superior rectus, except at the point of insertion. Traction on the cord with a squint hook lifted the conjunctiva along a line passing directly to the trochlea, so that the cord was demonstrably an aberrant superior oblique muscle. It looked just as if some one had tucked the round belly of the muscle under the nasal edge of the superior rectus and fastened it there, except that there was no scarring or fibrosis, and no previous operation had been performed.

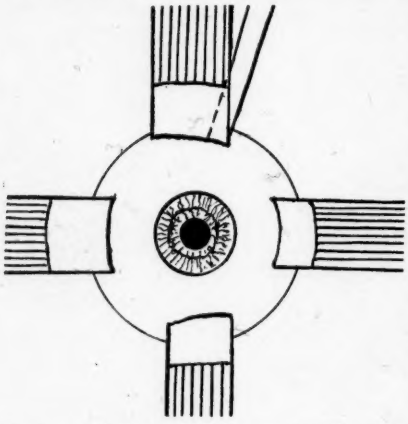

FIGURE.—Diagram of right eye to show abnormal insertion of superior oblique under nasal edge of superior rectus.

The pre-operative finding of right hyper-

* Received for publication April 7, 1952.

phoria on dextroversion suggested that this aberrant oblique was causing an excessive elevator action. The muscle was therefore separated and re-inserted in its proper place below and external to the superior rectus, and posterior to the equator of the globe. The lateral third of the superior rectus and an equal breadth of the inferior rectus were detached and stitched to the insertion of the external rectus in the usual way.

It is rather early to judge the result, but at this stage, ten days after operation, there is a right hypophoria of 4△ which increases to 13△ on looking right. This compares with 5△ hyperphoria on looking right before operation. Apparently the oblique in its new position is too effective. The eye is now capable of about 15° abduction compared with none before.

Comment

It is quite possible that this abnormality is not so uncommon as one might think. The white glistening cord can easily be mistaken for a piece of Tenon's capsule and be severed by the surgeon without his realizing its real identity. The writer recalls seeing somewhat similar cords before and entertaining a suspicion that they did not accord with normal anatomical relationships.

If the abnormality proves to be a common accompaniment of congenital paralysis of the external rectus muscle this case would suggest that the re-insertion should be less temporal than the normal position to avoid giving it a mechanical advantage in excess of requirement.

The case was referred to me by Mr. C. Gordon Sinclair, to whom I express my thanks.

REFERENCES

DUKE-ELDER, S. (1949). "Text-book of Ophthalmology", vol. 4, p. 4068. Kimpton, London.
HEUCK, G. (1879). *Klin. Mbl. Augenheilk.*, **17**, 253.

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ACTINOMYCOSIS OF THE CANALICULI*
WITH INVASION OF TISSUE IN ONE CASE

BY

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London

ACTINOMYCOSIS infection of the lacrimal canaliculi is a well-recognized condition in ophthalmic practice. Invasion of the tissues of the host is well known in other parts of the body but there appears to be only one previously recorded case where the canaliculi have been invaded (Chesneau, 1908).

Examination may reveal a swelling in the region of the punctum which superficially may look like a meibomian cyst, but this condition does not occur here. If, on milking the canaliculus, a purulent discharge is noted, the diagnosis is almost certain (Theodore, 1950).

In all the cases here recorded the punctum was patulous; in the opening a dirty white mass could be seen but the concretions could never be expressed manually. These concretions require to be curetted out and are hard and friable but can be crushed between a slide and cover slip for microscopic examination. The term " sulphur-granule " is misleading, as the colour is more often a dirty-white with a greenish tinge rather than yellow. The diagnosis can thus be made on clinical grounds alone, but all these cases were confirmed microscopically.

Reports of the frequency of the condition vary. Kipp (1902) reports that of 101,100 eye conditions treated in 21 years only three had this affection, and that in the Brooklyn Eye and Ear Hospital only four cases were noted in 32 years out of a total of 181,729. Wissmann (1913), however, states that it forms 2 per cent. of all *lacrimal* diseases. In the past 2 years I have a record of six cases, and it would thus appear to be not too uncommon. It is even possible that the condition may be becoming more frequent because of the increase in the use of antibiotics, causing suppression of the normal bacterial flora which may produce a factor inhibitory to the growth of the fungus.

TREATMENT

It is pleasing to find such a condition where the line of action is clear and dramatic in its results. The punctum is dilated and split for 1 mm., or just sufficient to admit a small chalazion spoon, and the concretions are curetted out. The quantity of material which can be obtained is often remarkable. The small slit in the canaliculus does not appear to disturb the drainage of tears. No further treatment has been required, and no case has recurred. I have tried other (conservative) measures such as the infiltration of the area with high concentrations

* Received for publication May 8, 1952.

of penicillin and the instillation into the lacrimal sac of aqueous penicillin or a 1 per cent. tincture of iodine or potassium iodide but without success.

Case Reports

All six cases were female and, apart from one old lady of 86, were between 30 and 45 years of age. It is dangerous to draw conclusions from such a tiny series, but this frequency in women agrees with the majority of previously recorded cases and as this is the characteristic age group and sex in which "idiopathic" epiphora occurs it would appear that that embarrassment of tear drainage is a necessary factor to encourage the growth of the anaerobic fungus. However, Brinckerhoff (1942) and McClanahan (1936) describe cases in males aged 19 and 14 years respectively.

In three cases the lower canaliculus was involved, in two the upper, and in the remaining one both were affected.

All the cases cleared up within a few days of the removal of the concretions, and the lacrimal passages were freely patent both before and after treatment.

Case 6, Housewife, aged 40, complained of a mucopurulent discharge from the right eye for the past year. She had been given penicillin drops during this time with no improvement. Examination revealed a normal white eye without any signs of follicular conjunctivitis. The lower punctum was gaping with a dirty white plug in its mouth. Near the caruncle, in the line of the canaliculus, there was a white mass the size of a grain of corn bathed in mucopus (Figure). The diagnosis of actinomycosis was confirmed microscopically in the pus and later in the actual concretion (see below).

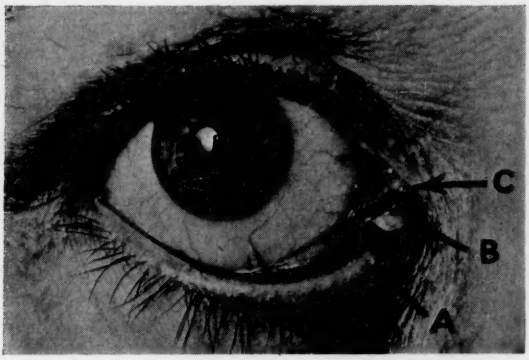

FIGURE.—Case 6, before treatment. A, position of punctum; B, site of erosion of canaliculus wall; C, position of caruncle.

The punctum was slit for 1 mm. and the concretions curetted out. It was then apparent that the fungus had eroded through the wall of the canaliculus on to the conjunctival surface; a probe could be passed through the slit punctum and out through the wall of the canaliculus, emerging just in front of the caruncle.

No further treatment was given and a month later the patient was free from symptoms, and stated that the discharge had cleared up within a few days of treatment. The canaliculus had healed over with some puckering of the conjunctival surface but the lacrimal passages could be syringed freely and there were no false openings. Probably it would have been better to curette out the contents of the canaliculus in a retrograde manner through the site of erosion without slitting the punctum.

Bacteriological Examination.—Notes on the bacteriological aspects have been made in previous reports (Ruys, 1935; Hagedoorn, 1940; Elliot, 1940; McClanahan, 1930).

The following report was made by Dr. E. D. Hoare, Pathologist, Edgware General Hospital:

Material removed at operation by curetting the right lower canaliculus was rather dry and whitish-green in colour.

Film.—This showed the presence of pus cells and numerous Gram-positive threads showing true branching. The threads were 0.5μ–0.7μ in thickness, and varied in length from 3μ to an average of about 8μ although forms up to 40μ or 50μ were not uncommon. The staining of the rods and threads was irregular; they were not acid-fast.

Cultures.—Attempts at primary isolation on the surface of blood agar plates incubated aerobically and anaerobically were unsuccessful after 3 weeks' incubation. The material was incubated in the form of an 0.5 per cent. glucose agar shake culture, and after 6 or 7 days' incubation growth became evident. After 12 to 14 days a turbid band was present about 0.5 cm. in thickness and 1.5 cm. below the surface, consisting of a number of tiny colonies. Deeper in the medium discrete whitish colonies up to 1.5 mm. in diameter were seen, roughly spherical with a coarsely irregular surface.

These discrete colonies in the glucose agar shake culture were successfully grown on the surface of blood agar plates incubated anaerobically but not on those incubated aerobically. After 7 days' incubation the colonies were 0.75–1 mm. in diameter, opaque greyish-white, circular, with a dull and nodular surface. The organisms were of similar morphology to those seen in the films of the material, and were non-motile, non-sporing, Gram-positive, and non-acid fast. This organism had all the characteristics of *Actinomyces bovis Harz.*

SUMMARY

Actinomycosis occurs infrequently in ophthalmic practice but perhaps more often than the literature would suggest. Notes have been made in the past 2 years of six cases including one in which there has been invasion of the wall of the canaliculus. Only one such case appears to have been previously recorded.

REFERENCES

BRINCKERHOFF, A. J. (1942). *Amer. J. Ophthal.*, **25**, 978.
CHESNEAU, M. (1908). *Ann. Oculist., Paris*, **140**, 409.
ELLIOT, A. J. (1941). *Amer. J. Ophthal.*, **24**, 682.
HAGEDOORN, A. (1940). *Arch. Ophthal., Chicago*, **23**, 689.
KIPP, C. J. (1902). *Ibid.*, **31**, 395.
MCCLANAHAN, R. (1936). *Amer. J. Ophthal.*, **19**, 418.
RUYS, A. C. (1935). *British Journal of Ophthalmology*, **19**, 385.
THEODORE, F. H. (1950). *Amer. J. Ophthal.*, **33**, 1225.
WISSMANN, R. (1913). *Klin. Mbl. Augenheilk.*, **51** (pt. 1), 287.

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HYPERMETROPIC REFRACTIVE CHANGES IN A DIABETIC*

BY

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THE text-books often mention remarkable changes in the refraction of the eye in diabetics—both in the direction of hypermetropia and in that of myopia. This is said to be due to alterations in the refractive index of the cortex of the lens, probably brought about by osmotic changes. I recently had occasion to see a newly-diagnosed case of diabetes which proved to be of great interest.

Case Report

The patient was a man aged 29. On examination his fasting blood sugar was 300 mg. per cent. His visual acuity was 6/18 in both eyes without correction. The lenses and fundi were normal.

Three weeks later his visual acuity was 6/6 part in both eyes without correction, and was improved to:

Right Eye: 6/5 with $\frac{+0.50}{+0.50\ \downarrow 90}$ *Left Eye:* 6/5 with $\frac{0}{+0.50\ \swarrow 70}$

Ten days later he again complained of blurring of vision, and his visual acuity was found to be 6/18 in both eyes without correction. This time it was improved to:

Right Eye: 6/6 with $\frac{+3.00}{+0.50\ \downarrow 90}$ *Left Eye:* 6/6 with $\frac{+2.50}{+0.50\ \swarrow 70}$

He could then read J1 easily with glasses.

One month later, when his diabetes was fairly well stabilized, there were slight colloid body-like changes around the macular area of both retinae, and some "rubeosis" of the conjunctivae. His visual acuity was 6/6 part in both eyes without correction, and could be improved to:

Right Eye: 6/5 with $\frac{+1.00}{+0.50\ \downarrow 90}$ *Left Eye:* 6/5 with $\frac{+0.50}{+0.50\ \swarrow 70}$

Conclusions

Definite hypermetropic refractive changes in a diabetic varied considerably with the different phases of "*stabilization*". It therefore seems advisable to wait until final stabilization is achieved before prescribing correcting lenses, despite the patient's occupational needs.

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Brit. J. Ophthal., **36**, 526.

CORRESPONDENCE

OPERATIVE TREATMENT OF CONGENITAL PTOSIS

To the Editorial Committee of the BRITISH JOURNAL OF OPHTHALMOLOGY

DEAR SIRS—Mr. G. I. Scott's interesting and informative article on the operative treatment of congenital ptosis (*British Journal of Ophthalmology*, **36**, 362) will be of interest to all ophthalmic surgeons. He rightly stresses that where there is any action at all in the levator muscle, and even sometimes when there seems to be none, the best cosmetic and functional result is achieved by shortening this muscle, the only debatable point being which is the better method of approach to it.

Of late, the fashion has been to operate from the conjunctival surface—the Blaskovicz operation—, but I should like to put forward the claims and possible advantages of the cutaneous approach, which seem to me to be these:

(1) The operation is performed with the tissues in their normal position and not turned upside down and put under tension by some kind of retractor.

(2) The incision through the skin occupies the exact site of the superior palpebral sulcus, and the slight scar left by it, so far from being a disadvantage, actually completes the normal appearance of the lid. Even in the best results by the Blaskowicz method, there is usually a small fold of skin in the upper lid obscuring this sulcus.

(3) The levator expansion, which is what one is really after in this operation, is rather more easily exposed by the skin approach, as it occupies a position in front of the tarsus, and thus the danger of advancing Muller's muscle in mistake for the levator is avoided.

(4) The muscle can be sutured to the tarsal plate by sutures which are left buried, as in any other advancement or resection operation, and then there is no silk thread passing through the whole thickness of the lid and so forming a possible track for infection.

By the cutaneous method the operation becomes exactly comparable to an advancement or resection of any other extra-ocular muscle, and, owing to the better exposure of the levator by this route, the excision of a piece of the tarsus is not necessary.

It would be interesting to know whether ophthalmic surgeons who have tried this method prefer it to the Blaskovicz technique.

Yours faithfully,

SEYMOUR PHILPS.

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July 23, 1952.

Brit. J. Ophthal., 36, 527.

BOOK REVIEWS

Ocular Surgery. By H. ARRUGA. Translated from the 3rd Spanish edition by M. J. Hogan and L. E. Chaparro. 1952. Pp. 936, 1,293 illus., 127 in col., bibl. Salvat Editores, Barcelona; McGraw-Hill, New York and London. (£21 5*s*.)

An event of considerable ophthalmological importance is the appearance of Arruga's "*Ocular Surgery*", translated from the third Spanish edition into English. It will be remembered that the first edition of this magnificent work appeared in 1946, and the second, translated into French by Blum of Geneva, in 1950; the present volume appears in English, having been translated by Michael Hogan and Luis Chaparro.

This unique text-book is now so well known as not to require a detailed description. It is sufficient to say that it covers the whole of ophthalmic surgery, the text comprising descriptions of the techniques used by Arruga himself, supplemented by the more important procedures and modifications appearing in the literature and used by other surgeons. In this present volume recent advances in ocular surgery have been fully noted, but the character of the main text, with its carefully outlined and full descriptions of operative procedures, its authoritative recommendations, its clear and informative writing, and its multitude of excellent illustrations, remains unaltered. Among text-books of ophthalmic surgery it is surely unique, and the English-speaking world is indeed indebted to Arruga and his translators for giving it the benefit of the author's wide practical experience and ripe judgment.

Clinical Ophthalmology (Ophtalmologie clinique). By PAUL BONNET. 1952. Pp. 1,294, 410 figs, 15 col. plates. Doin, Paris. (*Fr.* 11,000; £12.)

This is a long book made up of large, closely-printed pages, and at first glance one might be tempted to think it too long. But Professor Bonnet is a *teacher* of long standing and his clinical descriptions are invaluable and indeed could not be bettered.

The book has been written for medical students and physicians as well as for those specializing in ophthalmology. The author has thus emphasized the general clinical significance of the ocular symptoms and signs and has fitted ophthalmology into its niche in general medicine.

No attempt is made to describe operative procedures, for which the author says special treatises ought to be consulted.

If we were pressed for criticism we would say that although in general the illustrations are good there are quite a number which are not up to the standard of the text. The book is, however, a distinct contribution to ophthalmic literature, and we ought to be grateful to the author for having written it.

Principles of Refraction. By S. J. BEACH. 1952. Pp. 158, 18 figs. Kimpton, London. (30*s*.)

This short handbook glides over the subject of refraction lightly but authoritatively. There is no pretence of discussing the underlying optical theory; there are no forbidding diagrams; everything is simplified, and the practice of refraction explained and its implications discussed in a pleasant and interesting way, but, at the same time, with much common sense. The book will hardly be sufficient for the beginner; its greatest value will be in disillusioning the prejudiced practitioner.

NOTES

INSTITUTE OF OPHTHALMOLOGY

SESSION 1952-1953

THE Inaugural Lecture will be delivered by Sir Harold Himsworth, K.B.E., M.D., F.R.C.P., the Secretary of the Medical Research Council, at 4.30 p.m. on Tuesday, September 30, 1952, in the Lecture Theatre of the Institute of Ophthalmology. The title of the lecture is "Specialization and Research". As space is limited, early application for tickets should be made to the Secretary of the Institute.

During the afternoon the Institute will be open to visitors, who will be welcome in the various departments. Afternoon tea will be served at 4 p.m.

The Annual Dinner will be held at the Rembrandt Rooms, Thurloe Place, Kensington, S.W.7, on September 30 at 7.30 p.m. for 8 p.m. Tickets (price £1 each) may be obtained from the Secretary, Institute of Ophthalmology, Judd Street, London, W.C.1. Dinner jackets will be worn.

AMERICAN OPHTHALMOLOGICAL SOCIETY

OFFICERS, 1952-1953

President: - -	Dr. Conrad Berens
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SIR STEWART DUKE-ELDER, K.C.V.O., F.R.C.S., has been appointed Surgeon-Oculist to Her Majesty the Queen.

MR. A. J. B. GOLDSMITH, F.R.C.S., has been appointed Surgeon-Oculist to the Royal Household.

MR. R. C. DAVENPORT, F.R.C.S., has been elected to the Board of Examiners of the Royal College of Surgeons of England as an examiner in the final F.R.C.S. with Ophthalmology.

WE regret to announce the death of MR. CEDRIC COHEN, F.R.A.C.S., of Sydney, Australia. An obituary will appear in a later issue of this Journal.